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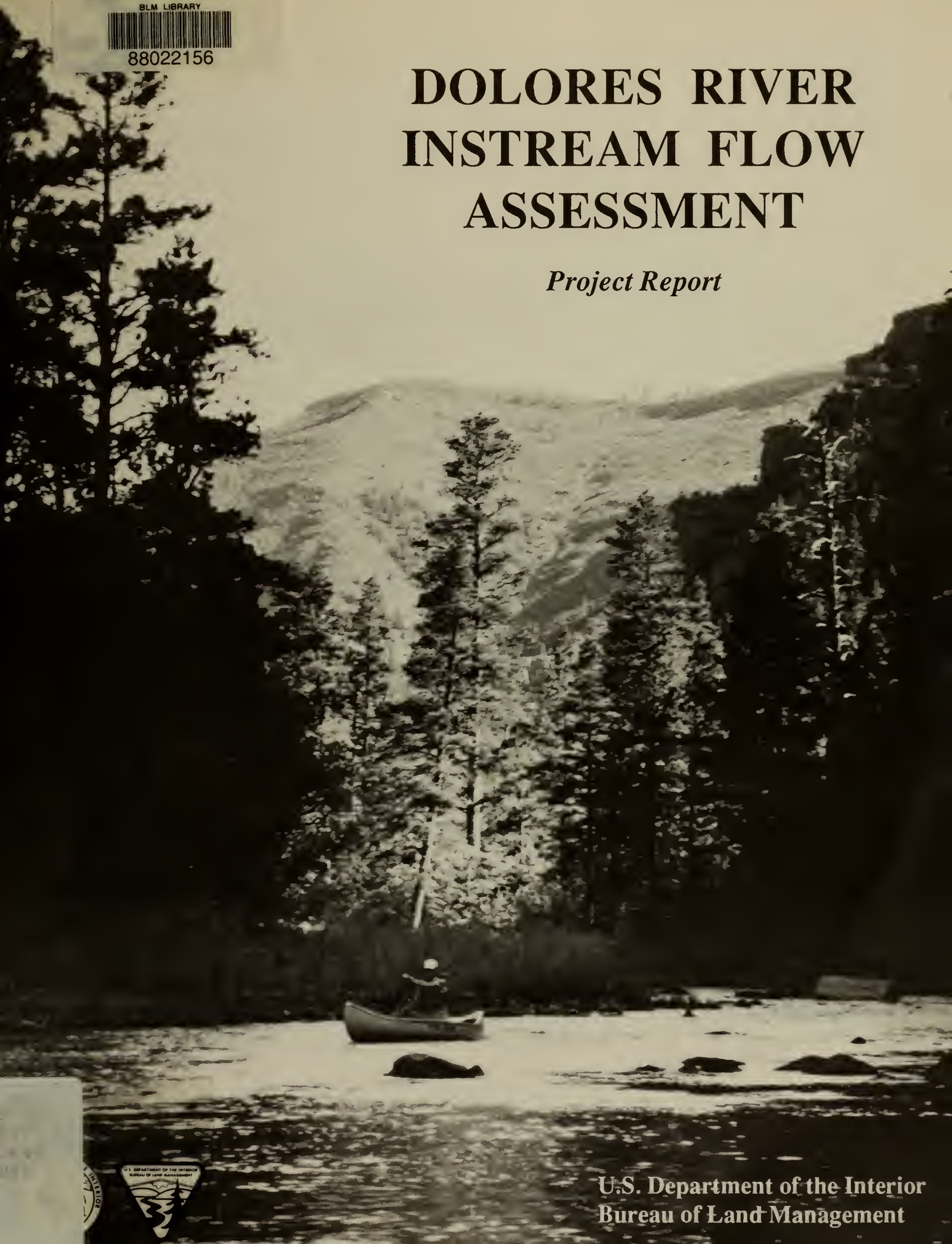
DOLORES RIVER INSTREAM FLOW ASSESSMENT

Project Report



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Bureau of Land Management

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DOLORES RIVER INSTREAM FLOW ASSESSMENT

Project Report

by

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The Montrose District of the Bureau of Land Management is responsible for managing a wide variety of water-dependent resources in the 94 mile segment of the Dolores River from Bradfield Bridge to Bedrock, Colorado. The Dolores River Instream Flow Assessment is designed as a technical reference to aid in future decision making and management of that segment of the Dolores River. The assessment documents the existing post-McPhee dam streamflow regime, documents present flow dependent resource values found in the Dolores River corridor, analyzes water management options for securing instream flow protection, and identifies the water conditions needed to support resource management objectives.

It is important to recognize that the focus of this report is on only one segment of the Dolores River. Other segments of the river exhibit different physical characteristics and may be managed to meet different objectives. Consequently, the flow figures presented in this report may not be directly applicable to river segments upstream or downstream from the assessment area.

Sincerely,

Alan L. Kesterke

Alan L. Kesterke
District Manager

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EXECUTIVE SUMMARY

The Bureau of Land Management (BLM) is responsible for managing lands and resources adjacent to the Dolores River in southwestern Colorado. The BLM recently completed the Dolores River Corridor Management Plan, which prescribes a 10-year management program. Values associated with riverine resources include recreational boating, aquatic and riparian habitat, and other stream channel characteristics related to proper channel maintenance. Since the completion of McPhee Dam and Reservoir, located upstream of BLM managed areas, availability and quantity of instream flows to support resource uses have not been determined. In addition to BLM's typical management responsibilities along the Dolores River, certain portions of the river have been recommended for wilderness and wild, scenic, and recreational designations, under the Wilderness and National Wild and Scenic Rivers Acts.

The purpose of this report is to document the existing post-dam streamflow regime, present flow dependent resource values found in the Dolores River corridor, analyze water management options for securing instream flow protection, and identify the water conditions required to support resource management planning objectives. This report summarizes an instream flow assessment conducted on portions of the river that include the area covered by the Dolores River Corridor Management Plan. Specifically, the study reach of the river extends from Bradfield Bridge downstream to Bedrock.

In 1987, the Bureau of Reclamation completed construction and filling of McPhee Dam and Reservoir as part of the agency's Dolores Project, a participating project of the overall Colorado River Storage Project. Streamflows have historically been reduced by diversions that transport water for irrigation out of the Dolores River Basin. McPhee Dam was built to augment the diversions by capturing and storing water that is available at times other than the irrigation season. The historical diversions have reduced the average annual flow of the Dolores River by approximately 39 percent. According to the U.S. Bureau of Reclamation Dolores River Definite Plan Report, when McPhee Reservoir is fully developed, it will further deplete Dolores River flows by an additional 30 percent. Thus, 69 percent of the flow of the Dolores River above the dam has been depleted.

Flow dependent resource values identified and analyzed in this report are related to: 1) recreation, 2) fish and wildlife, and 3) channel morphology. Flow dependent attributes analyzed under the recreation category were floatability and quality of whitewater to provide for a variety of experiences in kayaks, canoes, and rafts. Streamflow determinations for fish included an analysis of weighted usable habitat to support four life stages of brown and rainbow trout. Maintaining channel form, function, and sediment transport were studied as flow dependent characteristics under the channel morphology category.

In order to manage instream flows on the Dolores River, an analysis of institutional, market, and legal options was initiated. The Dolores River is fully appropriated. Therefore, opportunities for increasing streamflows within the study area depend on finding ways to reallocate existing uses of the river. Legal options only address ways in which existing or reallocated releases may be protected from future water depletions. This analysis of options did not include an in-depth study of alternative water reallocation costs and feasibility. Further analysis of this sort is planned for the Dolores River.

Flow requirements for boating, fish habitat, and channel maintenance are presented in the report. This report does not recommend annual flow requirements due to the need for further evaluation of water availability and river management objectives. It is noted that the flow requirements, presented in cubic feet per second (ft^3/s), involve resource tradeoffs, such as boating flows versus fishery flows). Annual flow scenarios will vary, depending on water availability. Five possible flow scenarios for management to consider are detailed in the summary of this document. Scenarios are provided to help management gain insight about differences in the flow scenarios relative to water availability and resource tradeoffs. Flow scenarios are examples of annual requirements, and not management alternatives.

Flows required for recreation values are sorted according to type of craft and floating experience desired. For canoeing experiences, 125 ft^3/s is required for float/fishing while scenic canoeing requires 300 ft^3/s. Rafting and kayaking experiences include scenic boating, minimum whitewater, and optimum whitewater, and the flow requirements for those experiences are 800, 1,100, and 2,000 ft^3/s, respectively.

Spawning and egg incubation flows of 125 ft^3/s (April 1 to June 30) are needed for rainbow trout and 65 ft^3/s (September 1 to March 31) for brown trout. Flows of 50 ft^3/s are required July 1 to August 31 for sufficient habitat for adult and juvenile brown and rainbow trout. Other life stages that occur during the above categories (e.g., rainbow fry) are protected by those flows.

Channel maintenance flows would be 2,000 ft^3/s for 7 days every other year. A maximum discharge of 500 ft^3/s is allowed for daily incremental changes. Given the 500 ft^3/s increments, the daily amounts on the rising and falling limbs of the hydrograph are 1,500, 1,000, and 500 ft^3/s, respectively.

INTRODUCTION

The Bureau of Land Management (BLM) is responsible for managing lands adjacent to the Dolores River in southwestern Colorado. Resources associated with this riverine ecosystem include outdoor recreation, aquatic habitat, cultural resources, and riparian vegetation. Many of the resource values associated with the management of the river ecosystem are dependent upon streamflow quantity. Since the completion of McPhee Dam and Reservoir, availability and quantity of instream flows to support boating, aquatic and riparian habitat, and maintenance of important stream channel and floodplain physical and biological characteristics and processes have not been determined.

BLM needs to know what flows are required to support those resource values it is responsible for managing. Furthermore, BLM needs to know what alternatives are available to protect those instream flows. Opportunities may be available for managing water supplies for the benefit of both instream and consumptive uses.

In 1975, the Interior and Agriculture Departments recommended "Wild and Scenic River" status for much of the river, including roughly 94 miles of the portion immediately downstream from Bradfield Bridge. The Wilderness Study Area (WSA) portion was recommended for "wild" status; other segments were recommended for "scenic" and "recreational" status. BLM (1989) continues to support these recommendations.

PURPOSE OF REPORT

The purpose of this report is to present to BLM management a clear picture of the flow-dependent resource values found in the Dolores River corridor, to identify streamflow conditions required to support resource management planning objectives, to document the existing post-dam streamflow regime, and to recommend to BLM management alternative strategies for securing protection for required streamflows.

BLM's recently completed Dolores River Corridor Management Plan (DRCMP) prescribes a 10-year management program for the river portion lying within the Montrose BLM District boundary (from the Bradfield Bridge to a point approximately 8 miles downstream of the San Miguel River confluence). The DRCMP primarily focuses on management of the highly unique and quite diverse recreational, biological, and cultural resources within this 106-mile corridor. Among the proposed management actions, the DRCMP addresses several cost and labor-intensive implementations. These actions include development of four to five river access sites, cultural and wildlife inventories and evaluations, riparian area monitoring, visitor education and interpretation efforts, and several other resource protection measures. Many of the proposed actions are based on the assumption that future downstream flows will continue to support resources currently found along the river corridor.

Because of the controlled flow situation now existing below McPhee Dam, this report comprises an instream-flow needs assessment of the river downstream of the reservoir. Results of this assessment project will be referenced in an appendix to the DRCMP.

PROJECT OBJECTIVES

The objectives of the Dolores River Instream Flow Assessment Project are to:

1. Determine the physical and legal availability of water for management purposes;
2. Develop relationships between streamflow and river resource values and evaluate the flow levels required to maintain those values; and
3. Identify and evaluate flow protection strategies and relate "protection realities" to management issues and goals.

In addressing the project objectives during the preassessment phase, several key assumptions and conditions emerged which complicate the water rights assessment:

1. The completion and filling of McPhee Reservoir have changed the pre-dam flow regime of the Dolores River below the dam.
2. The lower reach of the river (from Little Gypsum Creek to Bedrock) is within a Wilderness Study Area that has been recommended for wilderness designation.
3. Portions of the Dolores River corridor have been recommended for wild, scenic, and recreational designation under the National Wild and Scenic Rivers Act.

The project team incorporated these assumptions and conditions into the assessment.

DESCRIPTION OF THE STUDY AREA

Overview of Study Area

The Dolores River is a major tributary to the Colorado River, draining a northwest-southeast basin covering roughly 4,100 square miles in southwestern Colorado and 520 square miles in east-central Utah (Figure 1). The river flows for more than 200 miles, starting high in the San Juan Mountains (14,256-ft elevation) and descending to its confluence with the Colorado River near the Colorado-Utah state line (4,095-ft elevation).

In the course of its journey, the Dolores flows through five major western life zones, from the alpine at its headwaters to the upper sonoran along much of its lower reaches. Flows in the river vary seasonally. High flows result from spring snowmelt in the headwaters of the Dolores and San Miguel Rivers and in the La Sal Mountains of Utah. High intensity thunderstorms also cause localized peak flows intermittently during July, August, and September. Tributaries are ephemeral or intermittent, except for those draining high mountainous areas.

For purposes of intensive river corridor management, BLM (1990) has recognized two primary zones along the river. These zones coincide with the separate floating trip reaches traditionally described as "upper river" and "lower river" (Figures 2, 3, and 4). These zones also reflect distinctive characteristics of geology, vegetation, and hydrology. Zone 1, according to BLM (1990) is from Bradfield Bridge to the Disappointment Creek confluence. Zone 2 is the reach from the Disappointment Creek confluence to Bedrock and includes the Dolores River Canyon Wilderness Study Area.

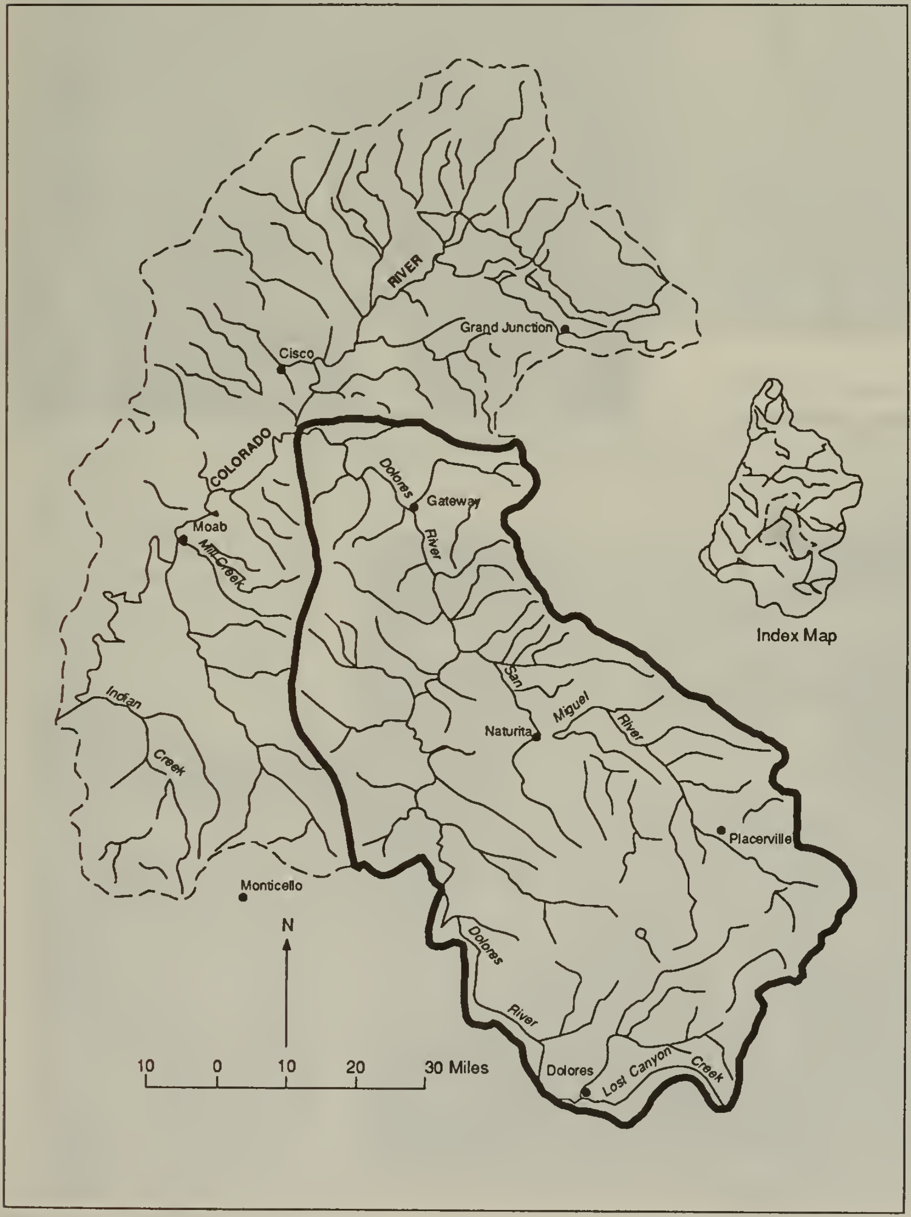


Figure 1. Dolores River Basin.

Much of the river corridor's scenic beauty stems directly from the spectacular geology of the various canyon segments. The Dolores generally flows from south to north in a deep canyon that is interrupted only where the river crosses Gypsum and Paradox Valleys. A series of anticlinal and synclinal valleys result from a sequence of northwest-trending folds within the area. Formations exposed along the corridor range from the Morrison Formation of Jurassic age to the Moenkopi Formation of Triassic age. The nature of the Dolores Canyon changes significantly downstream from Gypsum Valley. The upper segment (Bradfield Bridge to Disappointment Creek) is characterized by an average gradient of 24 feet per mile and sloping canyon walls covered with oakbrush, pinyon/juniper and tall ponderosa pines in the uppermost reach. The portion immediately below Gypsum Bridge changes to an average gradient of 11 feet per mile within a deeply-cut, extremely meandering slickrock canyon bearing predominantly pinyon/juniper and cactus-type vegetation on the canyon slopes. This meandering portion of the canyon was identified by BLM as a Wilderness Study Area in 1980 and was later recommended by BLM for actual "wilderness" status.

In 1987, the Bureau of Reclamation (USBR) completed construction and filling of McPhee Dam (Figure 5) and Reservoir as part of its Dolores Project, a participating project of the overall Colorado River Storage Project. Storage capacity of the reservoir is 381,000 acre-feet. Water pumped from McPhee will eventually be used primarily for irrigation; municipal and industrial uses will be secondary. Additionally, downstream river releases will provide some fish and wildlife enhancement, as well as recreational opportunities.

Figure 2. Upper Dolores River.

Figure 3. Confluence with Disappointment Creek generally separates upper and lower reaches of Dolores River.

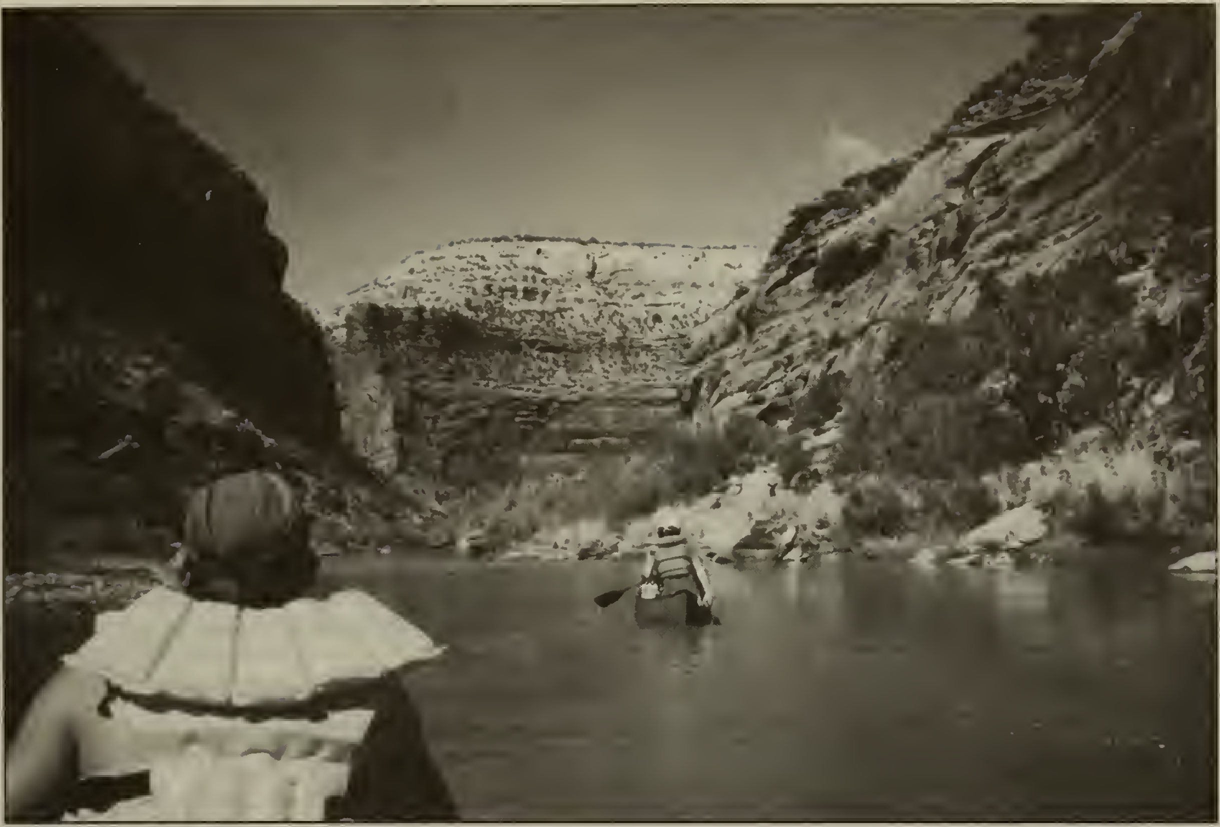


Figure 4. Lower Dolores River.

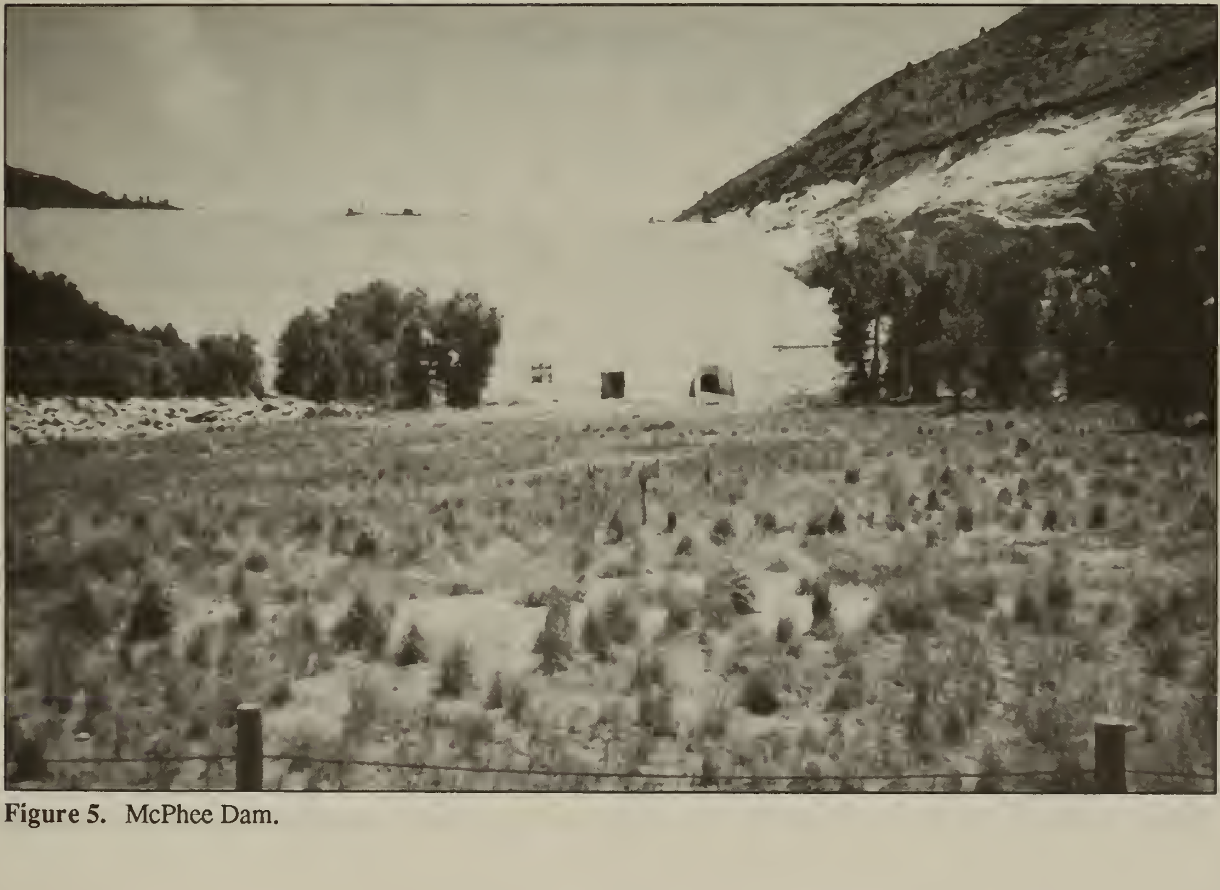


Figure 5. McPhee Dam.

Pre-McPhee Dam Hydrology

The Dolores River, in its headwaters, flows in a southwesterly direction to McPhee Reservoir. The river then turns to the northwest and flows into the Colorado River near Cisco, Utah (see Figure 1). Mean annual precipitation varies from approximately 8 inches at the mouth to more than 50 inches in the headwaters. Roughly 50 percent to 60 percent of this precipitation falls as snow. The mean annual flow of the river at the mouth was 763 ft^3/s, which equates to an annual yield of approximately 550,000 acre-feet. This does not include approximately 173,000 acre-feet diverted from the river for both in-basin and out-of-basin water use. For a summary of the basin's hydrological and physical characteristics, see Table 1.

The study reach is located about mid-watershed, as measured by river miles (see Figure 6), beginning at Bradfield Bridge approximately 11 river miles below McPhee Dam and ending roughly 94 river miles downstream from Bradfield Bridge at Bedrock, Colorado. Precipitation in the study area varies from about 12 to 16 inches annually. The drainage area between Bradfield Bridge and Bedrock is about 1,149 square miles or 25 percent of the Dolores River Basin.

The mean annual flow of the river at Bedrock was 465 ft^3/s. Mean monthly flow values for the

Table 1. Dolores River Basin Hydrological and Physical Characteristics

Station Name	Below Rico CO	At Dolores CO	Nr. McPhee CO	At Bedrock CO	At Gateway CO	Nr. Cisco UT
Period of Record	1951-81	1895-81	1938-53	1917-81	1936-54	1950-81
Comp Years	30	70	14	15	18	31
Drainage area (mi^2)	105	504	817	2,024	4,350	4,909
Station Elev. (ft)	8,422	6,919	6,666	4,940	4,548	4,165
Mean Basin Elev. (ft)	10,600	9,800	9,200	8,200	8,000	7,900
Channel Length (mi)	20	48	59	148	185	204
Annual Precip. (in.)	26	18	16	11	11	8
Mean Annual Flow (ft^3/s)	132	426	403	465	938	763
Land Class as a Percent of Basin Area						
Forest	99	93	90	65	45	40
Agriculture	0	5	6	15	15	15
Range	0	0	3	18	40	45
Water	1	1	1	1	0	0
Urban	0	1	0	1	0	0

Dolores River at Bedrock (lower boundary of study area) and at Dolores (20 miles above the upper study boundary) are shown in Figure 7.

Historically, flooding of the Dolores River has occurred from two different processes: (1) flooding during April, May, and June from snowmelt or snowmelt combined with rainfall, and (2) summer and fall flooding resulting from high- intensity rainfall events. Spring snowmelt floods are usually characterized by a large volume of runoff and extended peak flows occurring over a several week period. The basin above the study area can generally be divided into two snowpack zones which normally, during the snowmelt season, produce bimodal runoff peaks. The lower elevation zone includes an area dominated by gambel oak, ponderosa pine, and scattered aspen. The higher subalpine zone is characterized by engelmann spruce, subalpine fir, and aspen. The low-elevation zone melts off first, commonly producing a flow-peak in late April or early May. Peak flows from the melting of the subalpine zone usually occur in late May or early June.

The occurrence of flooding from rainfall events varies within the study area. The portion of the Dolores Basin within the study area is mostly semiarid, having sparse vegetation cover and significant acreage of rock outcrop. Consequently, surface runoff from rainfall events is much greater than in the basin above the study area, which is mostly forested. This is shown in Table 2 where, in a 10-year period from 1972-1981, the Dolores River at Dolores (above the study area) experienced all of the annual peak flows from snowmelt. However, the Dolores River at Bedrock had 3 (1972, 1974, 1977) out of the 10 years where summer or fall rainfall events produced the annual peak flow. Within the study area, annual peak flow events occurring from rainfall are most evident during years when the snowpack and subsequent snowmelt runoff are below normal.

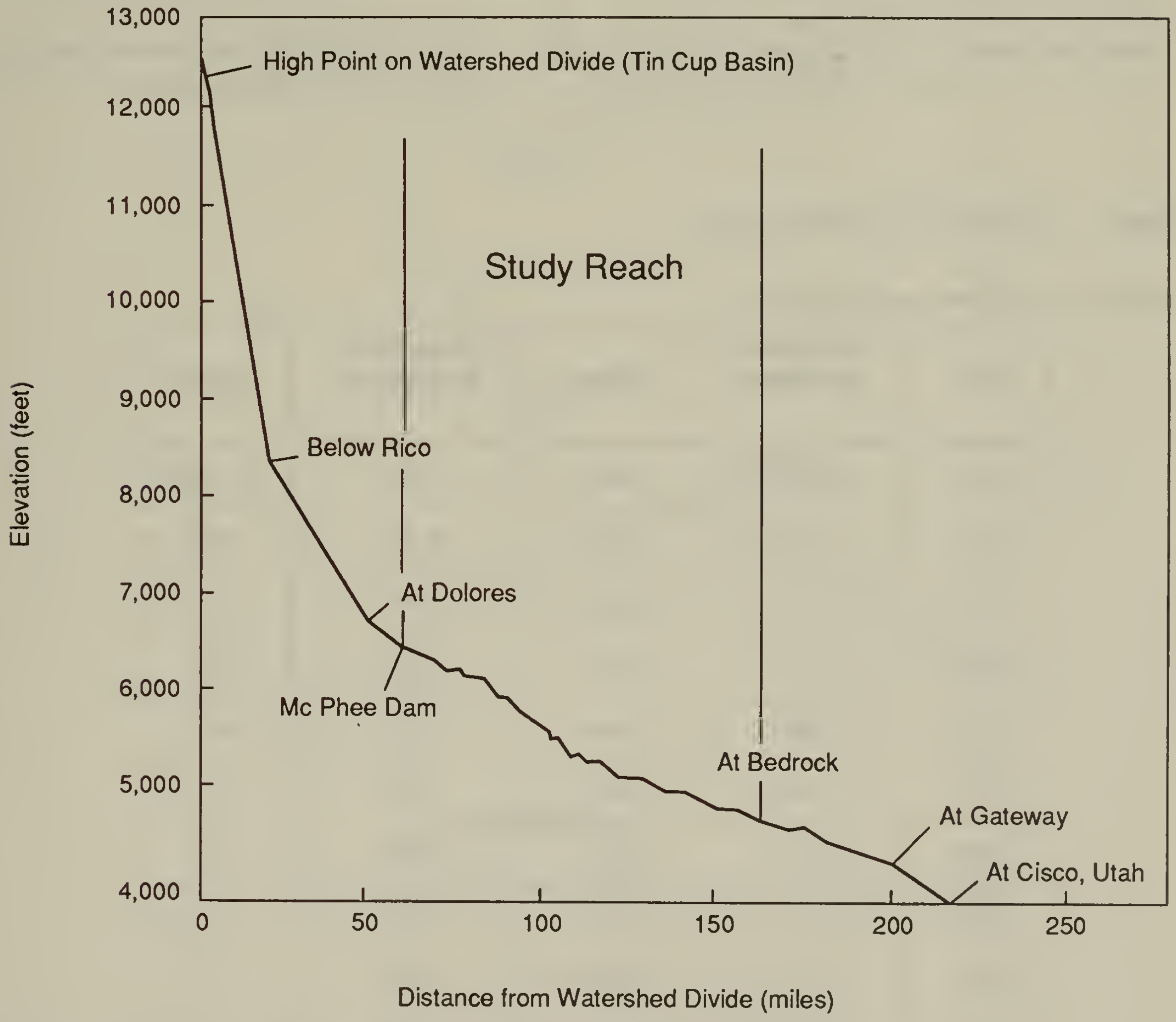


Figure 6. Dolores River profile.

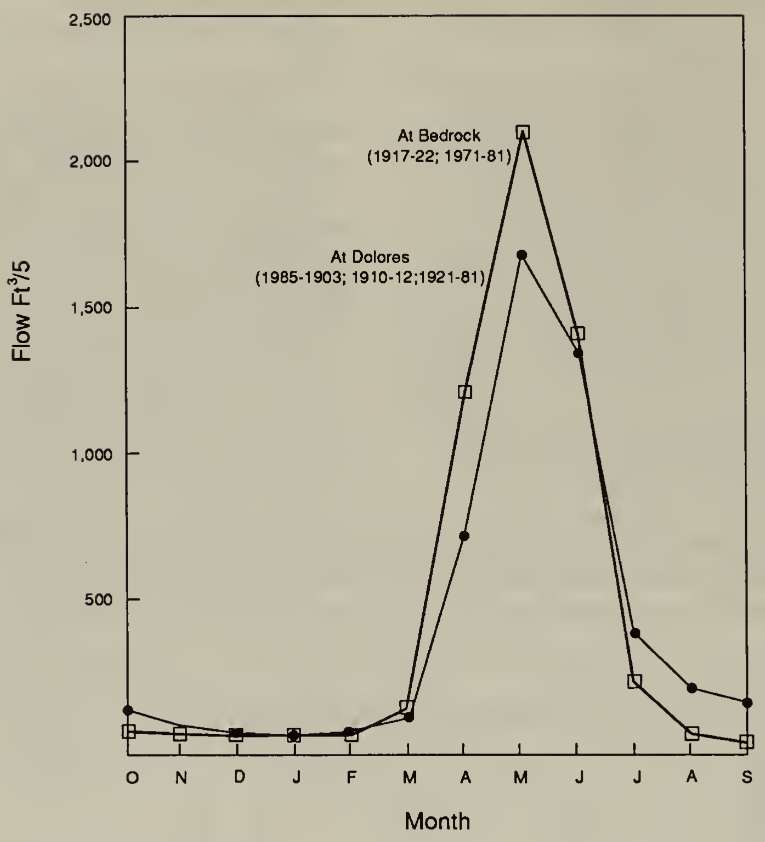


Figure 7. Dolores River annual hydrograph.

Table 2. Dolores River Annual Peak Flows

Year	Peak flow at Dolores	Month	Peak flow at Bedrock	Month
1972	1,660	June	1,920	October
1973	5,750	May	9,280	April
1974	2,070	May	3,430	July
1975	4,600	June	8,020	May
1976	2,640	May	2,310	May
1977	585	April	6,720	July
1978	3,440	May	4,450	May
1979	4,580	May	8,520	April
1980	4,900	June	8,700	April
1981	1,900	May	1,290	May

The historical diversions and impoundments on the Dolores River, discussed in later sections, have resulted in changes to both the seasonal flow regime and peak flow rates within the study area. The loss of water from the river system is more evident at low flows. This can be seen in Figure 7 where, from June through November, the mean monthly flows at Dolores were greater than the flows at Bedrock, 125 miles downstream. The data in Figures 8 and 9 specifically define these low flow impacts. For example, referring to Figure 8, the Bedrock 10-year, 7-day low flow was 0.1 ft^3/s, while at Dolores the same recurrence interval flow was over 22 ft^3/s. The flow duration curves in Figure 9 indicate that the low flows at Dolores exceeded the low flows at Bedrock more than 75 percent of the time.

The impacts to peak flow rates from water diversions are more significant at the lower Recurrence Interval (RI) events. As can be seen in Figure 10, the 1.5-year RI peak flow is essentially the same for both Bedrock and Dolores.

However, as the RI increases, so does the difference between the peak flows at these two stations. This possibly results from the water diversions becoming less significant with higher flows, and the higher flows being more a function of drainage basin features such as runoff characteristics, climate, and basin size.

The natural occurrence of high flows in a river system provides the energy needed to maintain the river's fluvial features. The bank-full discharge has been found to be the most dominant or effective flow for maintaining these features. The bank-full discharge is defined as the stage of a river channel above which the banks are overflowed onto the floodplain. This discharge closely correlates to a 1.5-year RI flood event (calculated from an annual flood series, or a 0.90 RI if calculated using a partial series). On the average bank-full flow is equalled or exceeded 4-7 days annually (Leopold and Dunne, 1978). Table 3 compares the 1.5-year RI peak flow for gauging stations at Dolores, near McPhee, and at Bedrock, against the 1.5-year 7-day high flow. Without the historic water diversions below the Dolores station, it would be expected that the peak and 7-day high flows for both McPhee and Bedrock would be somewhat higher. In addition the period of record used for the flow calculations at the McPhee

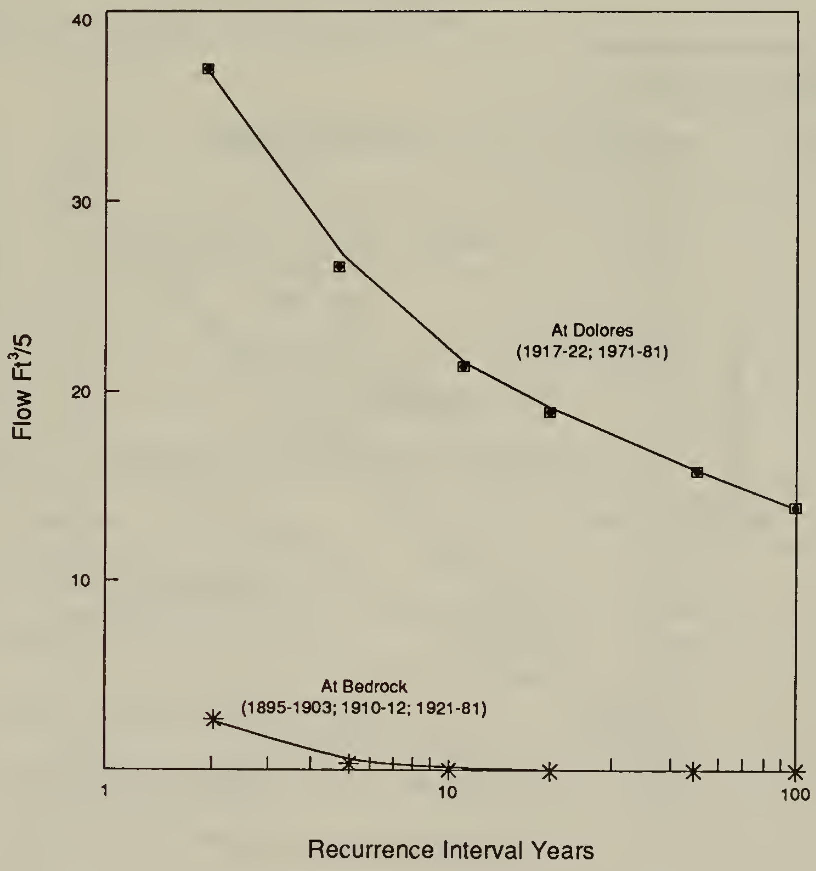


Figure 8. Dolores River 7-day low flow statistics.

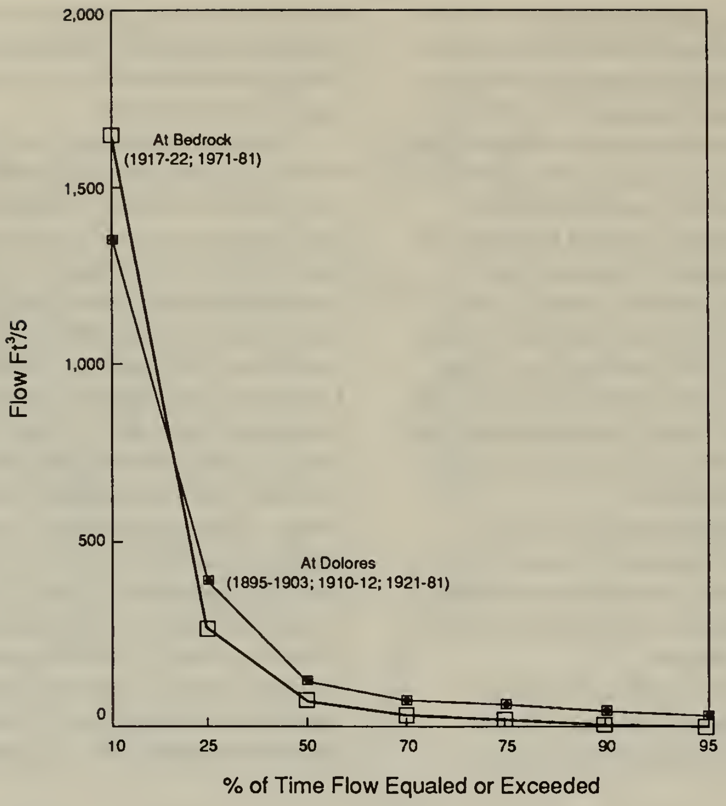


Figure 9. Dolores River flow duration.

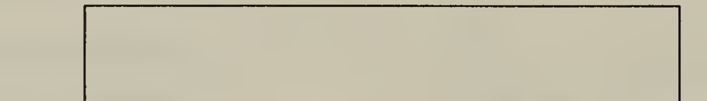


Figure 10. Dolores River peak flow statistics.

station was wetter than the long-term average, which has probably overestimated the flows for McPhee shown in Table 3. With these considerations in mind, and by comparing the data in Table 3 to field data collected in 1989, the pre-dam bank-full discharge for the upper reaches of the study area is estimated to be 2,000-2,500 ft^3/s (Table 4). Since the pre-dam bank-full flow usually occurred from snowmelt flooding, a progressive downstream increase in the bank-full discharge would be expected as a result of tributary inflow. At Bedrock this expected increase is on the order of 300-500 ft^3/s.

The available sediment yield data for the Dolores River (Irons et al., 1985, USDI, 1974) indicates that there is a substantial progressive downstream increase in Total Suspended Sediment (TSS). Data collected just above the study reach showed a TSS yield of 182,000 tons annually (0.34 tons/acre/year), whereas the Dolores River at Cisco yielded 2,254,000 tons annually, (0.80 tons/acre/year). Sediment yield per acre characteristically decreases with increasing drainage area. However, due to the high runoff and erosion potential of the semiarid Lower Dolores Basin, the situation here is reversed.

Within the study area the primary sediment contributor is Disappointment Creek. Being one of the few perennial tributaries in the study area, Disappointment Creek's confluence with the Dolores River is about 5.5 miles upstream from the town of Slick Rock at river mile 124. The Disappointment drainage is about 350 square miles and is largely comprised of highly erodible saline soils. Data collected at USGS gauging station 9168100, roughly 19 miles upstream from the confluence, shows the mean annual flow of Disappointment Creek to be about 17 ft^3/s (annual water yield of 12,300 acre-feet). Specific data on the sediment yield of Disappointment Creek is not available, but from regional data (USDA, Soil Conservation Service, 1974) it is estimated to be 225,000 to 500,000 tons per year (1-2 tons/acre/year). Disappointment Creek also degrades the water quality of the Dolores River with salinity. During the 1984 water year, an estimated 10,000-11,000 tons of salt were discharged in the flows at the above-mentioned gauging station (USDI, 1986). This does not include the 200 square miles of drainage below the gauge.

Table 3. Bank-full Flow Estimates at USGS Gauging Sites

Station	Period of Record	1.5-Year Recurrence Interval	
		Peak Flow (ft^3/s)	7-day High Flow (ft^3/s)
At Dolores	1895-1903, 1910-12, 1921-83	2,589	2,045
Near McPhee	1939-1952	2,964	2,110
At Bedrock	1918-22, 1972-83	3,068	1,808

Table 4. Bank-full Flow Estimated at Selected Locations Within the Study Area

Location	Bank-Full Flow
Bradfield Bridge	2,000
Dove Creek Pump Station	2,000
Below Disappointment Creek	2,200
Below Gypsum Valley	2,300
Above La Sal Creek	2,400
At Bedrock	2,500

Post-McPhee Dam Hydrology

The average annual yield of the Dolores River above McPhee dam is 349,900 acre-feet (see Table 5). Of this flow, approximately 136,100 acre-feet has historically been diverted by the Montezuma Valley Irrigation Company (MVIC), and 6,900 by other senior water right holders. An average of 206,900 acre-feet of water remains in the Dolores River to be captured by McPhee Reservoir. When in full operation, McPhee Reservoir would deplete the Dolores River by an additional 106,400 acre-feet (99,600 acre-feet project water + 5,400 acre-feet for evaporation + 1400 acre-feet bank storage).

Flows in the Dolores River below McPhee Dam would average 105,400 acre-feet a year. These flows would consist of 3,900 acre-feet released for downstream water rights, 25,400 acre-feet of project water released specifically to improve the Dolores River fishery, and 76,100 acre-feet of surplus snowmelt runoff that could be spilled or released in anticipation of spills. The 1,600 acre-feet of water reserved for future fish and wildlife uses would be stored in McPhee Reservoir until the location and nature of use were determined.

Of the 76,100 acre-feet of surplus snowmelt runoff, about 66,000 acre-feet would be released on a scheduled basis in anticipation of spills from mid-April to the end of June to provide whitewater boating opportunities in the river below McPhee Dam (USBR, 1977).

Table 6 shows the effects of the project on streamflows during typical wet, normal, and dry years. The minimum flows in the river below McPhee Dam would be maintained at 78 cubic feet per second (ft^3/s) during wet years (13 years of the Definite Plan Report (DPR) 46-year study period or 28 percent), 50 ft^3/s during normal years (23 out of 46 years or 50 percent), and 20 ft^3/s during dry years (10 out of 46 years or 22 percent). In the DPR simulated operation, a wet year was considered to begin on May 1 and extend for 1 year if the end-of-April elevation of McPhee Reservoir exceeded 6,914 feet (82 percent of the active capacity). A dry year would begin on March 1 and extend for a year if the March 1 prediction of the elevation of McPhee Reservoir at the end of June was less than or equal to 6,892 feet (45 percent of the active capacity). A normal year was assumed to occur when the end-of-April elevation was less than 6,914 feet (82 percent of the active capacity) and the March 1 prediction of the end-of-June elevation was greater than 6,892 feet (45 percent of the active capacity). The minimum flows are composed of releases for downstream users, spills, and the project releases to improve the stream fishery (USBR, 1977).

In summary, historical diversions have reduced the average annual flow of the Dolores River by approximately 39 percent. When fully developed, McPhee Reservoir will further deplete Dolores River flows by an additional 30 percent. Thus, 69 percent of the historic flow of the Dolores River will be depleted by MVIC diversion and McPhee Reservoir.

The Bureau of Reclamation Operations Studies for McPhee Dam were limited to monthly flow values. Four offices of the Bureau of Reclamation were contacted in an attempt to locate a daily operations model for McPhee Reservoir. Finding none, the " Puls" method was used to route an inflow hydrograph through McPhee Reservoir. This method assumes a constant discharge-storage relationship for the reservoir being assessed. For a given time interval, the change in storage is computed and outflow is determined by the discharge-storage relationship.

The purpose of this simplified routing method was to determine the 7-day high flows that potentially could be released to the Dolores River below McPhee Dam. The 7-day high flows were determined to represent the channel forming/bank-full flows as described in the Pre-McPhee Dam Hydrology section. Historic daily flows from the Dolores near McPhee streamflow station for the years 1939 to 1952 were utilized as inflows. Outflows were determined utilizing the "Puls" method described above with the following assumptions:

1. The previous End Of Month (EOM) reservoir storage elevation from the USBR Reservoir Operation Study (Definite Plan Report, April 1977) was used for the beginning reservoir elevation for each month simulated.

2. The area capacity curve in the DPR was used for operations purposes. The reservoir was considered full at a stage of 6,928 feet and a capacity of 381,000 acre-feet. The spillway elevation was set at 6928 feet. The outlet works were essentially closed requiring all flows to go over the spillway.

Table 5. Average Annual Allocations of Dolores River at McPhee Dam[1] (From USBR 1977)

Nonproject water	**Acre-Feet**
MVIC irrigation	130,600
MVIC stock and domestic	5,500
Cortez senior rights	3,000
Downstream senior rights	3,900
Total nonproject yield	143,000
Project yield	
Irrigation	
MVIC area	13,700
Dove Creek area	54,300
Towaoc area	22,900
Subtotal	90,900
Municipal and Industrial	
Cortez	6,200
Dove Creek	600
Towaoc	1,000
Dolores Water Conservancy District	900
Subtotal	8,700
Fish and Wildlife	
Dolores River fishery	25,400
Reserved for future development	1,600
Subtotal	27,000
Total project yield	126,600
Project losses, spills, and change in content	
Evaporation from McPhee Reservoir	5,400
Evaporation and conveyance loss from Monument Creek Reservoir	200
Spills from McPhee Reservoir	76,100
Average annual change in McPhee Reservoir content (1928-1973)	-1,400
	80,300
Average Annual flow into McPhee Reservoir	**349,900**

[1] The average annual adjusted flow of the Dolores River at McPhee Dam for the period 1928-73 is 349,900 acre-feet. The Dolores River was gauged at McPhee Dam site from 1939 through 1952. The McPhee gauge data were adjusted for the effects of Groundhog Reservoir operations and the MVIC diversions and then correlated (one analysis for each month) with the historical flow of the Dolores River at Dolores (1928-73) adjusted for Groundhog.

Table 6. Representative Monthly Flows With and Without the Project—Dolores River at McPhee

	Wet Year (second-feet)		Normal Year (second-feet)		Dry Year (second-feet)	
	Pre-Project	Post-Project	Pre-Project	Post-Project	Pre-Project	Post-Project
March	140	90	100	60	70	20
April	2,190	920	980	60	170	20
May	1,280	1,940	1,420	240	470	20
June	1,150	460	1,030	290	130	20
July	60	78	70	50	0	20
August	30	78	70	50	20	20
September	20	78	100	50	10	20
October	20	78	90	50	20	20
November	30	78	50	50	40	20
December	40	78	60	50	40	20
January	40	78	50	50	50	20
February	50	78	60	50	50	20

Source: USBR, 1977

3. The maximum allowable diversions, based upon the total capacity of the Dolores Tunnel and the Great Cut Dike (1,340 ft^3/s), were subtracted from the computed spills.

4. The resulting outflows are only to be used as an indication of potential 7-day outflows to the Dolores River after total completion of the Dolores Project.

Of the 14 years of record modeled, the following 7-day high flows were determined for the upper river:

8 years or 57 percent had flows greater then 700 ft^3/s
7 years or 50 percent had flows greater than 900 ft^3/s
6 years or 42 percent had flows greater than 1100 ft^3/s
5 years or 36 percent had flows greater than 1300 ft^3/s
4 years or 28 percent had flows greater than 2500 ft^3/s
1 year or 7 percent had a flow greater than 3700 ft^3/s

From this analysis it was assumed that the 1.5-year recurrence interval 7-day high flow will be approximately 1,000 ft^3/s for the upper river. Thus the channel forming flows expected to be released after full development of the Dolores Project are approximately 1000 ft^3/s.

The outlet works at McPhee Dam, as stated in the DPR and verified in conversations with the Cortez Project Office (personal communication, Mr. Mutz, Oct. 1989), will be operated to allow for release through the outlet works of inflow design floods between 1,000 and 2,500 ft^3/s. Releases of flows greater than 2,500 ft^3/s would only occur under extreme situations.

Actual 7-day high flow releases to the Dolores River based upon operations of a full reservoir (1987-1989) are as follows:

May 87: 7 days greater than 2,319 ft^3/s
May 88: 7 days greater than 1,087 ft^3/s
May 89: 7 days greater than 1,001 ft^3/s

The construction of McPhee Dam has no effect upon inflows from side drainages in the study area. The only streamflow record for tributaries to the Dolores River below McPhee is for Disappointment Creek. The 1.5-year 7-day high flow for Disappointment Creek near Dove Creek was 104 ft^3/s.

No data are available for other tributaries to the Dolores River. Table 7 is an estimate of post-dam 1.5-year recurrence interval discharges for selected locations on the Dolores River within the study area.

The low flow or baseflow of natural free-flowing rivers results from subsurface (ground water or interflow processes) discharges occurring within the drainage basin. These processes are critical for sustaining perennial flow in river systems during periods of low precipitation. If baseflows are depleted, the river becomes intermittent and the resources dependent on the perennial flow, such as fisheries, are lost or significantly reduced.

The baseflow of a river system can be affected by various processes occurring within the drainage basin. As a river flows downstream, baseflow can increase from additional ground water inflow (effluent river system) or decrease through recharge to ground water systems (influent river system). Other common losses to baseflow are man-related consumptive water uses, evaporation from the water surface and channel banks, and transpiration from riparian vegetation.

The Colorado Water Conservation Board has filed an instream flow right for 78 ft^3/s between McPhee and the confluence with the San Miguel River. This flow rate was determined from data collected by the Colorado Division of Wildlife near the Bradfield Ranch in the early 1970's (personal communication, Norwin Smith, Colorado Division of Wildlife, 1989). According to the Colorado Water Conservation Board's Instream Flow Appropriation Tabulation, the 78 ft^3/s flow is applicable to the reach between McPhee Dam and the confluence with the San Miguel River. The subject study area is nested within this reach.

According to the USBR's bypass release schedule, 78 ft^3/s would only be released in an above-average water year. In average and below average water years, the minimum release would be 50 and 20 ft^3/s, respectively. Wet-, normal-, and dry-year release schedules were discussed earlier in this section.

To determine low flows necessary to protect resource values defined by BLM, streamflow gains or losses were identified in the study area. In Figures 11, 12, and 13, 1989 summer flows at McPhee Dam are plotted against those at Bedrock. Starting around mid-May 1989, the dam release was gradually reduced from 600 ft^3/s to approximately 78 ft^3/s on June 6. It took about 20 days, until June 26, for the flows at Bedrock to stabilize at around 60 ft^3/s. This time lag resulted from the slow release of channel bank storage, slow streamflow velocities, and some precipitation that occurred on June 10 and 12. It is also possible that seasonal water diversions were

Table 7. 1.5-Year Recurrence Interval Flow Estimates for the Dolores River at Selected Locations Post-McPhee Dam

Location	Post-Dam Bank-full (ft^3/s)
Bradfield Bridge	1,000
Dove Creek Pump	1,000
Below Disappointment Creek	1,200
Below Gypsum Valley	1,300
Above La Sal Creek	1,400
At Bedrock	1,500

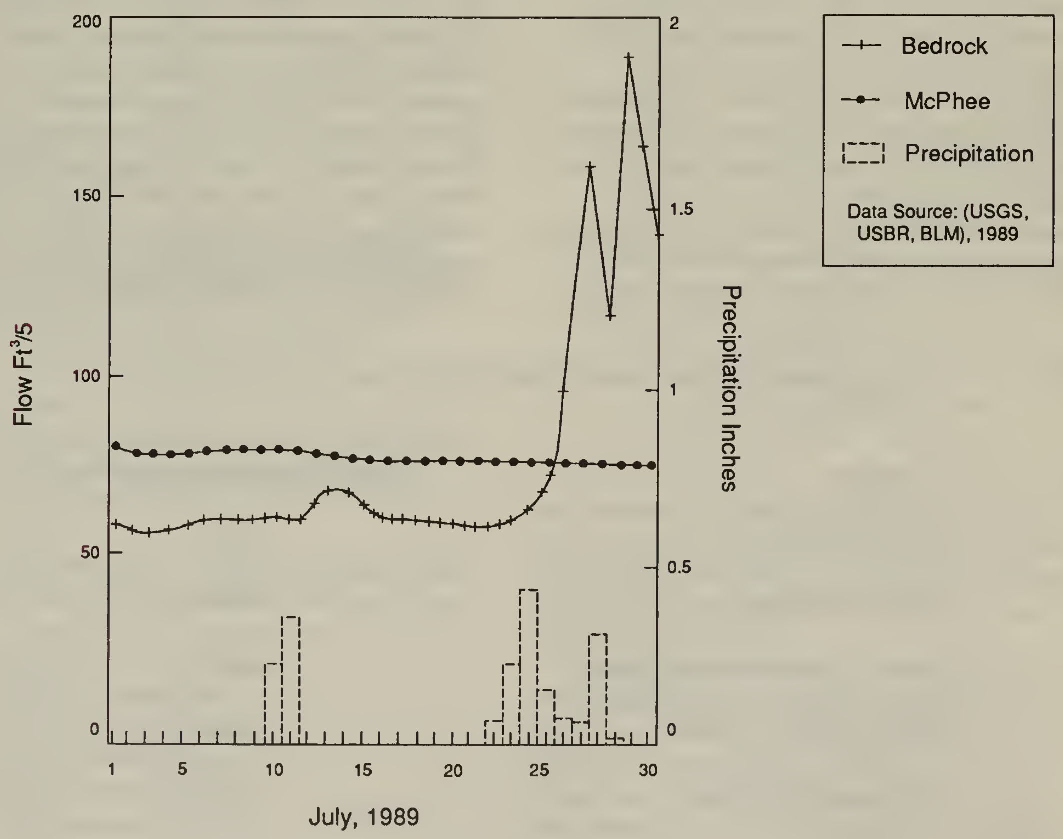
initiated during this time. The runoff produced from precipitation in the study area shows at the Bedrock station, while the dam release remains constant. If these runoff events are overlooked, it can be seen that for June, July, and August, the Bedrock flows tend to stabilize near 60 ft^3/s. This equates to an 18 ft^3/s loss in flow between McPhee Dam and Bedrock. For the most part, the summer of 1989 was drier and warmer than average which would tend to maximize the low-flow losses. It should also be noted that during cooler months, when evapotranspiration rates and irrigation withdrawals are lower, low-flow losses would not be as great.

During the summer of 1989, BLM made several discharge measurements on the Dolores River to determine how and where the 18 ft^3/s loss was occurring. The average discharges measured at selected points within the study area are shown in Figure 14. The difference in discharge between sites (i.e., water loss) correlates well with channel distance, especially if the "in use" water rights (see Table 8) between sites are taken into consideration. This indicates that most of the water loss is occurring from evapotranspiration along the water course and from man-related water diversions. Water loss or gain to or from ground water systems appears to be insignificant. Also, water gains from tributary inflows were minimal (e.g., Disappointment Creek, at its confluence with the Dolores River, was dry most of June and July and flowing less than 0.10 ft^3/s in August).

Table 9 shows how the 18 ft^3/s loss would affect the three bypass release flows (i.e., 78, 50, and 20 ft^3/s) at selected points in the study area. A worst case scenario is also presented which includes diversions for all valid existing water rights with appropriation dates prior to 1975 (see Table 9). Presently "in-use" water rights are assumed to be part of the 18 ft^3/s loss, while inactive water rights are factored in, continuously using their full appropriation. As previously mentioned, the 18 ft^3/s loss was determined during a summer release of 78 ft^3/s. It is possible that at the lower releases of 50 and 20 ft^3/s losses would be greater due to higher water temperatures.

Based on river resource values analyzed in this report, changes in water quality resulting from operation of McPhee Reservoir are negligible.

see errata sheet inside front cover



Data Source: (USGS, USBR, BLM), 1989

Figure 11. Dolores River low flow - McPhee vs. Bedrock, June 1989.

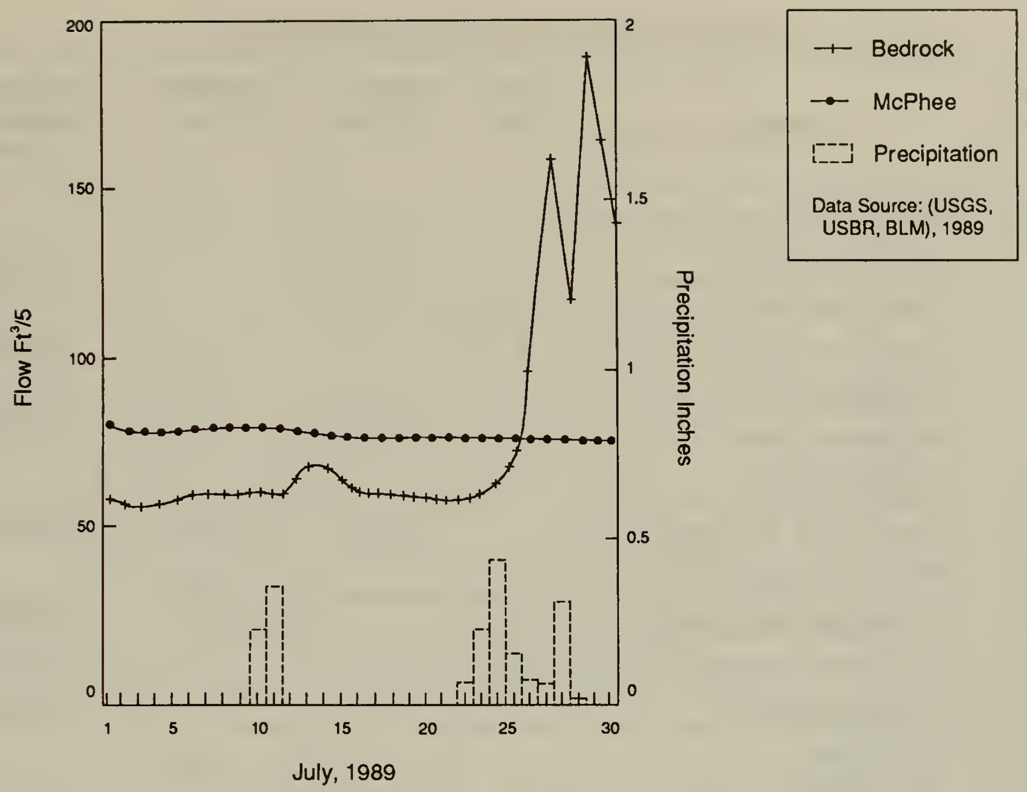


Figure 12. Dolores River low flow - McPhee vs. Bedrock, July 1989.

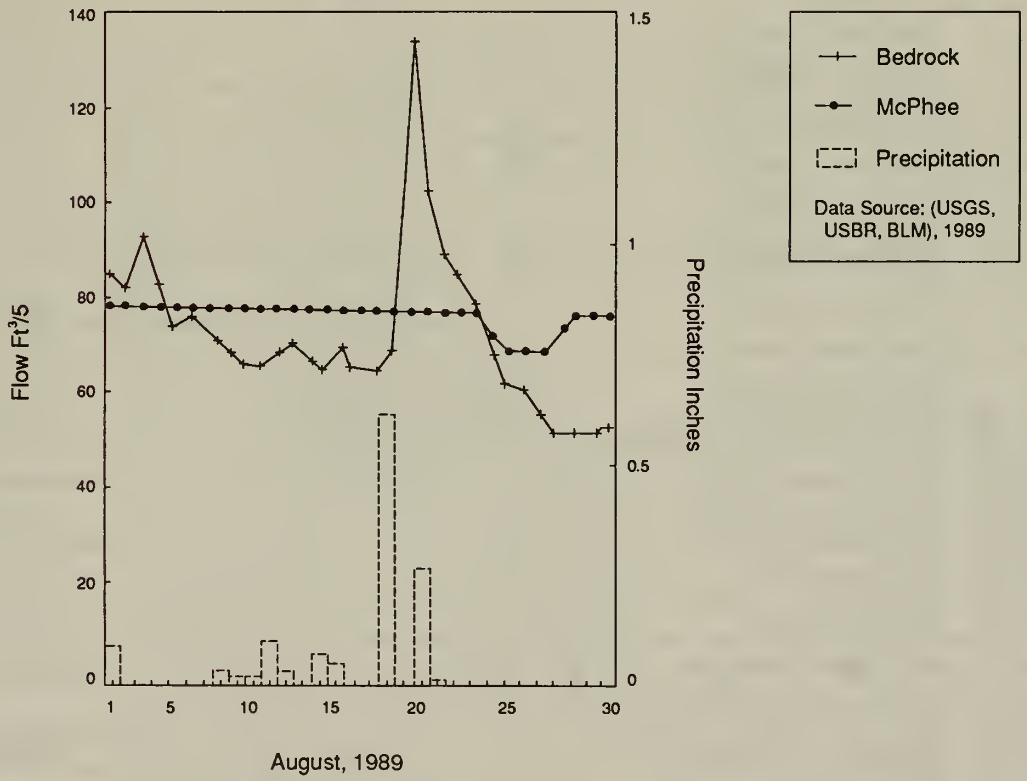


Figure 13. Dolores River low flow - McPhee vs. Bedrock, August 1989.

Table 8. Water Rights TabulationDolores River - McPhee Dam to Bedrock, CO

River Mile	Name	In Use Y/N	Absolute (ft^3/s)	Conditional (ft^3/s)	Adjudication Appropriation Dates
180	McPhee Dam	—	—	—	—
176	Geo P. Moore Ditch	N	0.70		1892/1881
173	Lone Dome Ditch	N	1.00		1892/1892
173	Lone Dome Ditch	N	1.20		1892/1891
170	DD Williams Ditch	N	1.00		1891/1881
170	DD Williams Ditch	N	1.00		1892/1891
167	Bradfield Bridge	—	—	—	—
148	Dove Cr. Dd. Rv. Supply	Y	0.870	0.210	1968/1951
148	Blw Dove Creek Pump	—	—	—	—
124	San Miguel Pump Plant #2	N		5.00	1979/1979
119	Troy Rose Diversion	N	2.00		1968/1908
119	Chuck Wagon Well	Y	1.00		1972/1924
118	Slick Rock	—	—	—	—
118	Burro Well #1	N	0.067		1971/1958
118	Burro Well #2	N	0.111		1971/1958
117	Correll Well	Y	0.100		1972/1959
116	Slick Rock Well #1	N	0.111		1971/1956
116	Slick Rock Well #2	N	0.156		1971/1957
116	Slick Rock Well #3	N	0.056		1971/1958
116	Slick Rock Well #4	N	0.111		1971/1958
116	Slick Rock Well #5	N	0.111		1971/1958
116	Slick Rock Well #6	N	0.156		1971/1958
116	Slick Rock Well #7	N	0.111		1971/1958
116	Slick Rock Well #8	N	0.111		1971/1958
116	Slick Rock Well #9	N	0.111		1971/1956
116	Lawrence E. Rogers Ditch	N	1.50		1937/1919
108	Suckla Pump Site	Y	3.50		1978/1935
106	Bullington Pump Site	N			1977/1915
106	Will Rogers Ditch	N		1.5	1977/1923
104	Bullington Ditch	N		2.00	1977/1915
104	Will Rogers Pump Site	N		1.50	1977/1923
104	Gypsum Valley BLM Put-In	—	—	—	—
69	AELRP & PL Blw WSA	Y	7.5		1969/1959
69	Bedrock Bridge	—	—	—	—

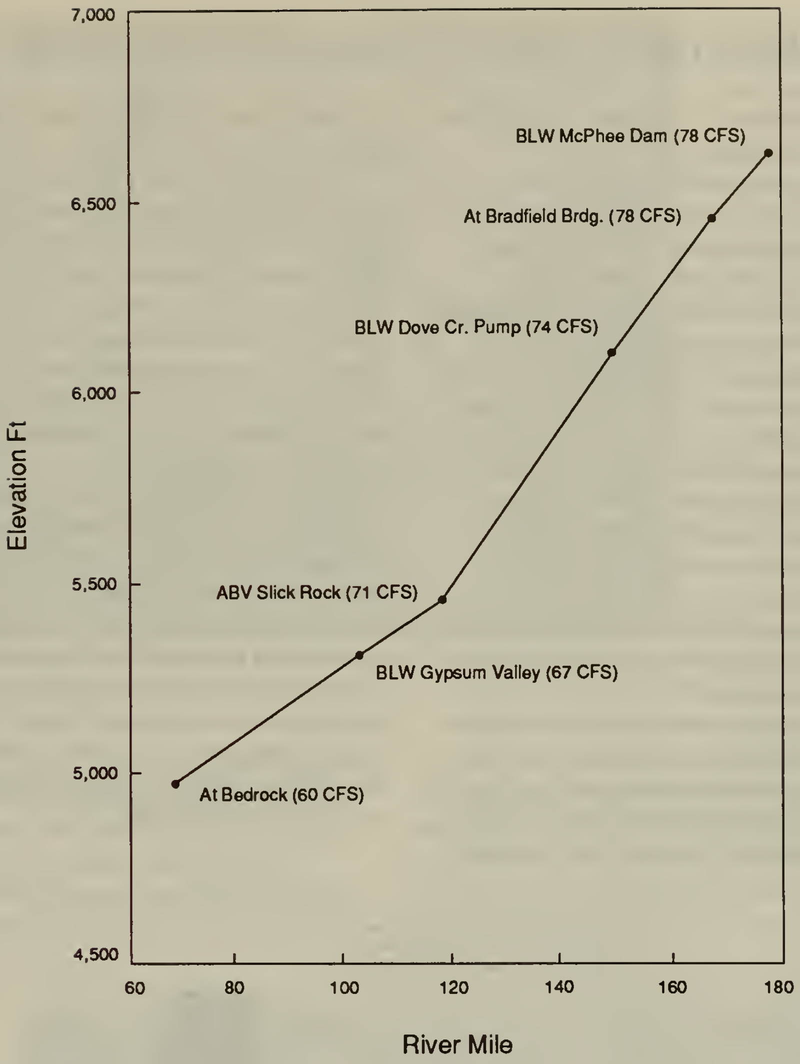


Figure 14. Dolores River discharge during low flow (Data Source: BLM, USGS, USBR, 1989).

Table 9. Dolores River Summer Low Flow Estimates

River Site	Present Situation Bypass Release (ft^3/s)			Worst Case Bypass Release (ft^3/s)		
At McPhee Dam	78	50	20	78	50	20
At Bradfield Brdg.	76	48	18	71	43	13
Blw. Dove Creek Pump	74	46	16	69	41	11
Abv. Slick Rock	71	43	13	66	38	8
Blw. Gypsum Valley	67	39	9	52	24	0
At Bedrock	60	32	2	45	17	0

Descriptive River Channel Morphology

The Dolores River has developed a combination of gradient, pattern, and hydraulic variables that allow it to transport water and sediment loads efficiently (i.e., with a minimum expenditure of potential energy). These fluvial features are closely interrelated and both control and respond to the expenditure of the river's energy. The Dolores River exhibits a classic concave longitudinal profile (see Figure 6), with the channel gradient decreasing from the headwaters to the mouth. This profile is, in part, the river system's means of controlling the rate at which velocity increases downstream. The concave profile is often interrupted locally where gradient steepening and lowering occurs between pools and riffles, and where bedrock outcrops or geologic formations change.

River reaches are often classified according to their position on the longitudinal profile. Reaches at or near the headwaters typically have fewer depositional features (i.e., riffles, bars, alluvial floodplains, etc.), a lower sinuosity, steeper gradients, and larger bed material, when compared to river reaches closer to the mouth. Even though the study area is located in the middle portion of the Dolores River longitudinal profile, the channel morphology does exhibit some of these characteristics. As an example,

Figure 15 shows a progressive increase in channel sinuosity from Bradfield Bridge to La Sal Creek. The channel gradient above the Disappointment Creek confluence averages 0.4 percent while the gradient below averages 0.2 percent. A significant difference also occurs in the median bed material size (d_{50}). Near the Dove Creek Pump Plant the d_{50} was measured at 222 mm while the average from several transects near the confluence of Disappointment Creek was 60 mm.

Resistance to flow in the Dolores River is caused by both skin friction and form resistance. Skin friction refers to flow resistance caused by obstructions to flow, primarily bed material and vegetation. As shown in the comparison of bedload sizes above, skin friction resulting from bed material decreases downstream. At present, vegetation is not a significant contributor to the skin friction within the bankfull channel. However, under a reduced flow regime, woody vegetation will invade depositional features such as bars (Figure 16).

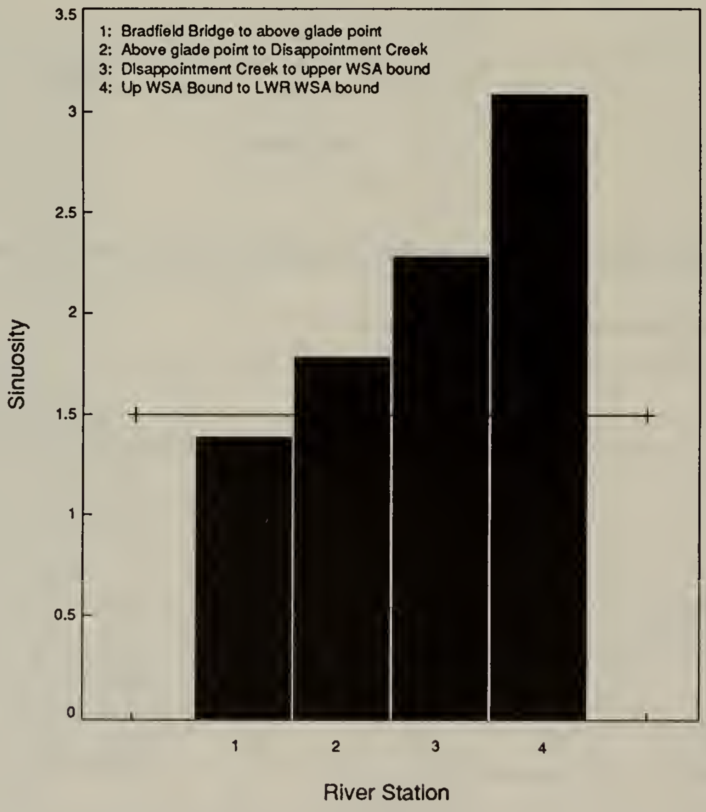


Figure 15. Dolores River sinuosity McPhee Dam to La Sal Creek.

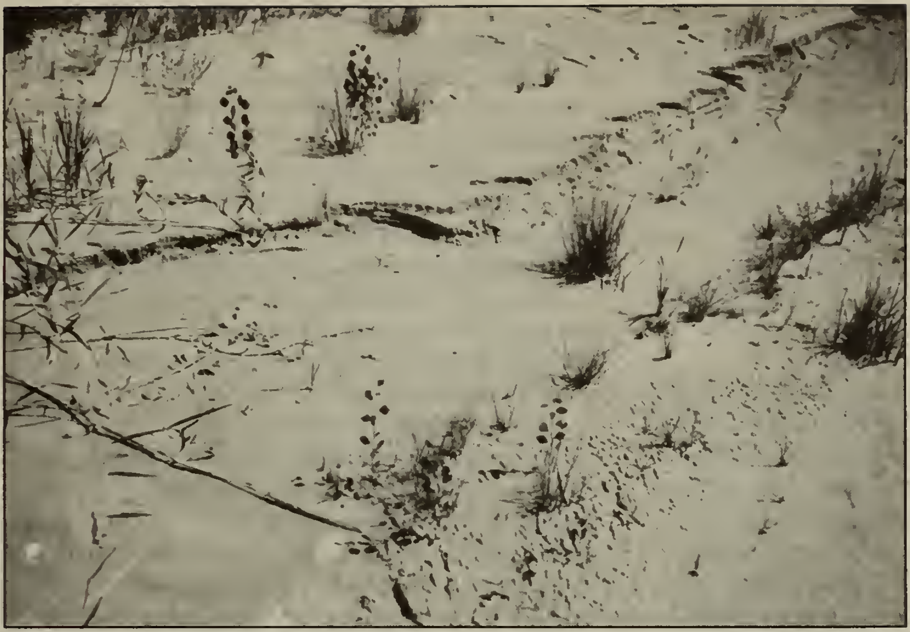


Figure 16. Establishment of cottonwood seedlings within historic bank-full channel, in Lower Dolores River.

Form resistance refers to flow resistance caused by either the channel pattern (e.g., meandering) or by fluvial channel features that cause irregular channel geometries such as pools, riffles, and bars. The elements of form resistance serve to dissipate stream energy by causing large turbulent features such as eddies, secondary currents, or plunge flows.

Bars can account for a large percentage of the total flow resistance in any given river reach (Figure 17). Bars may be classified as point bars (the inside of a meander bend), side bars (or alternating bars), mid-channel bars (exposed riffles), transverse bars (or diagonal bars), and tributary bars (bars created by tributary streams). Of particular concern for this study are both mid-channel and tributary bars because of their potential to affect the floatability of the river. Mid-channel bars result in channel braiding, and tributary bars are responsible for the formation and maintenance of many of the river's rapids. Both of these channel features are limiting factors for floating the river especially during low flows. Mid-channel bars are formed during high flows when a portion of the coarse sediment load is deposited because of some local channel condition. The most common occurrences of mid-channel bars in the study area are in unconfined reaches where unstable or easily erodible channel banks exist, and below tributaries that supply large sediment loads to the river. Pool areas, such as those upstream from constrictions in the channel, are also common locations for bars to form.

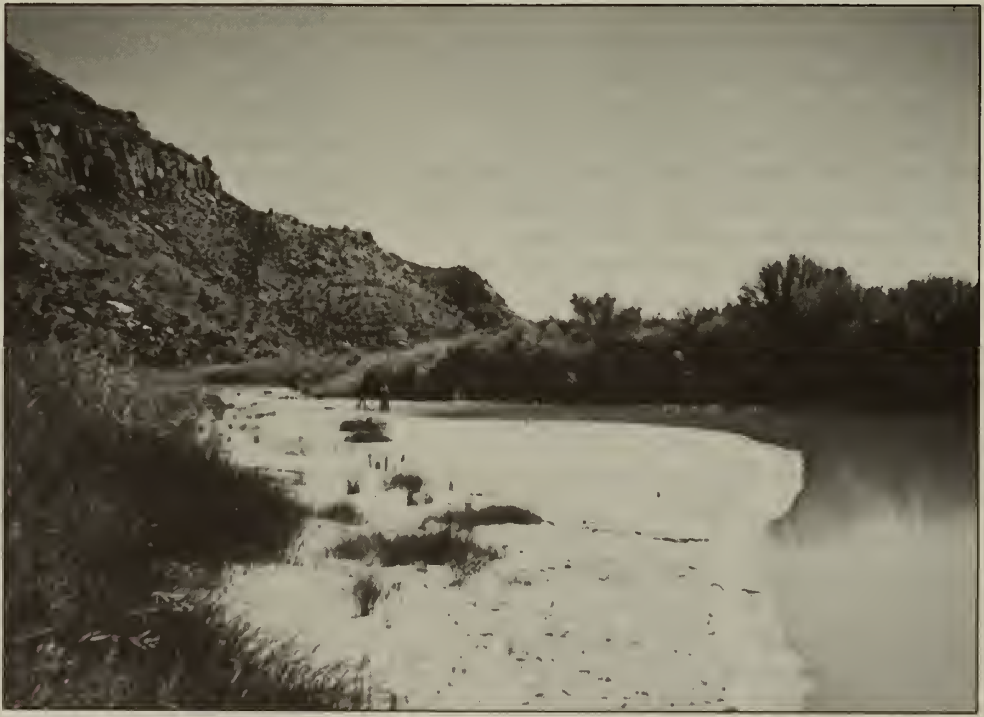


Figure 17. Point bar located in lower reach of Dolores River.

The mid-channel bars growth toward the surface tends to concentrate flow in the flanking channels, which in turn causes scouring of the channel bed and/or eroding of the channel banks. Bars, especially in rivers with controlled flow regimes such as the Dolores, tend to become stabilized with vegetation, which prevents them from being easily eroded and helps to trap fine materials during high flows. Braided zones resulting from mid-channel bar development usually have steeper channel gradients, and are shallower and wider than unbraided river reaches.

A tally of the prominent mid-channel bars in the study area can be found in Table 10. The reach from Bradfield Bridge to Dove Creek Pump Station has approximately 0.50 bars per mile, with most of them being closer to Bradfield Bridge. The bars in this reach appear to be resulting from instabilities in the channel banks, possibly from livestock grazing or recreational use. Unstable or easily eroded channel banks allow the channel to become wider and shallower, promoting the establishment of bars. Consequently, once the bars are formed, channel bank erosion is accelerated. The reach from the Disappointment Creek confluence to the WSA boundary has the highest occurrence of mid-channel bars at one per mile. As with the first reach discussed, the bars in this reach appear to have been enhanced from human related activities. However, this reach is the least confined section in the study area, and it receives a large sediment load from Disappointment Creek, both factors in mid-channel bar development. The reach within the WSA has 0.44 bars per mile. Several of these bars occur downstream from major tributaries (e.g., Spring Canyon, La Sal Creek, etc.) that deposit large sediment loads into the Dolores River. The confinement of the river in this reach is partially responsible for the low occurrence of mid-channel bars.

Tributary bars are formed where major side canyons deposit their sediment loads when they meet the Dolores River. Most of the rapids (Bull Canyon, Spring Canyon, La Sal Creek, etc.), especially in the lower part of the study area, are a result of these depositional features. Commonly, these alluvial deposits, extending out from the mouth of the side canyons, push the mainstem channel against the opposite bank until it encounters bedrock. High flows in the Dolores River determine channel width and slope through these deposits (rapids). Reducing the occurrence of high flows raises the possibility that the rapids may increase in gradient and decrease in width as tributary flooding adds new debris (Howard and Dolan, 1981).

A river channel is considered meandering when the sinuosity (channel length divided by straight-line down-valley distance) exceeds 1.5 (Ruhe, 1975). According to this definition the Dolores River for the entire length of the study area is considered meandering, with the exception of a few miles near Bradfield Bridge. Even though some of the sinuosity may be initiated and controlled by the local geologic structure, meandering channels expend large amounts of energy due to the work required when water changes its direction of flow. The meander sequence in alluvial channels has been found to closely correlate to the size and discharge of the river (personal communication, Dr. L. Leopold, 1989). On the average, one meander wavelength is equivalent in length to 10-14 times the bank-full channel width. The bank-full channel width in turn is predominantly controlled by the bank-full discharge, as previously discussed.

Pools are most commonly defined as relatively deep portions of the river channel experiencing converging flow, while riffles are more shallow than pools and occur in zones of diverging flow. In any given river reach, energy loss is greater than the average over riffles and less than the average in pools. In a meandering river, riffles are typically located between successive pools at the "crossover" (or inflection) point of the thalweg (Beschta and

Table 10. Tally of Mid-Channel Bars

River Reach	Number	River Miles	Number Per Mile
Bradfield Brdg. to Dove Cr. Pump Sta.	9	18	0.50
Dove Cr. Pump Sta. to Disappointment Cr.	9	25	0.36
Disappointment Cr. to WSA Boundary	22	22	1.00
WSA Boundary to Bedrock	14	32	0.44

Platts, 1986). Pools and riffles in nonmeandering river segments are usually synchronized with alternating bars. In either case the pool and riffle sequence is controlled by the meander or alternating bar pattern which in turn is controlled by the bankfull flow as described above.

In summary, the various fluvial features of a river system are highly dependent on one another for their existence. They are largely a product of the river's flow regime and sediment load (both size and amount). Altering either the flow regime or sediment load will result in adjustments, often simultaneously and unpredictably, of the river's fluvial features. Additional discussion of expected changes in the Dolores River's fluvial system resulting from the present operation of the McPhee Reservoir can be found in later sections of this report.

APPROACH AND METHODS

The Dolores River Assessment consists of the following six steps: (1) a preliminary assessment and study design; (2) the identification and description of flow-dependent resource values in the river corridor; (3) a description and quantification of hydrology and geomorphology; (4) a description of the effects of flows on resource values; (5) the identification of flows required to protect values; and (6) the development of a strategy to protect flows.

An interdisciplinary team was assembled to address the resource issues, hydrology and geomorphology, and legal and management options. Following completion of literature reviews, the team met in April 1989 to share results and devise a field data collection strategy. During the week of May 14, 1989, the entire team visited and canoed the river from Little Gypsum Creek through the Wilderness Study Area to the takeout at Bedrock. The primary emphasis of this field visit was to address floatability issues and review river resource values (Figure 18). River flows during the trip varied between 600 ft^3/s on May 15 to 125 ft^3/s on May 20.

Recreation Methods

Recreation methods involved four general steps: 1) assessing available recreation opportunities; 2) identifying specific values or trip attributes associated with those opportunities; 3) examining flow-attribute relationships; and 4) recommending flows necessary to ensure high quality recreation opportunities.

These steps were accomplished through several specific tasks, including an extensive review of literature written about the resource, on-site resource reconnaissance, interviews with "resource experts," and a survey of experienced users.

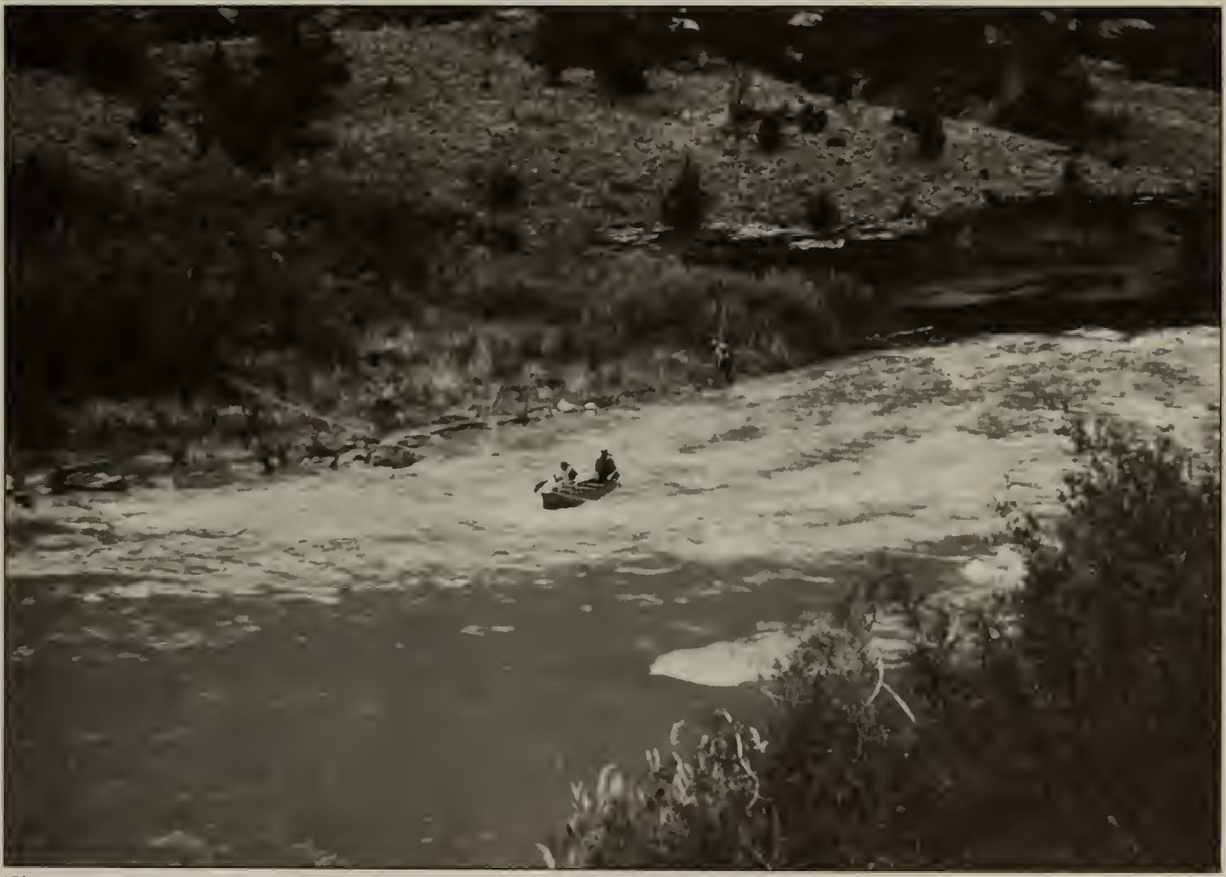


Figure 18. Cross-section measurement for floatability issues at Bell Canyon Rapids.

Literature Review

The literature review focused on recreation opportunities and trip attributes. The Bureau of Outdoor Recreation Wild and Scenic River Study, the Dolores River Canyon Wilderness Study, the recent Draft Management Plan for the river, and results from a survey of Dolores River users were four key sources, providing information about geographic context, physical features, recreation activities and use patterns, and recreation values. The survey of users, in particular, was useful in describing specific trip attributes which define the "Dolores River experience." This review also examined attribute-flow relationships, although there was significantly less detailed information available on this subject. Key sources included the Final Environmental Impact Statement from the McPhee Dam Project and the letters which followed from that document, as well as a pair of popular press articles about the impact of the dam on whitewater boating. A complete list of sources reviewed is given in Literature Cited section.

Resource Reconnaissance

Resource reconnaissance was conducted from May 15-20, 1989. Low flow conditions prevented a continuous float from Bradfield Bridge to Paradox; instead reconnaissance was conducted in three stages. The first stage involved a 3-day trip in fully packed canoes from Gypsum Bridge to Bedrock, while the next two stages involved day trips in lightly loaded canoes from Bradfield Bridge to Dove Creek Pump Station, and from Dove Creek to Snaggletooth Rapid. The section from Snaggletooth to Gypsum Bridge was not run, although team members viewed the canyon from Slickrock to Disappointment Creek. The team saw the lower canyon at flows ranging from 300 to 600 ft^3/s, while they saw the upper canyon at flows ranging from 125 to 300 ft^3/s.

On-site work for recreation focused on flow-attribute relationships. One key issue was determining minimum flows for floating critical navigability reaches (Figure 19). Because low flow conditions did not allow team members to examine rafting flows as well as canoeing flows, work focused on choosing reaches for hydrology cross sections to characterize flow-related recreation features. These could then be used to model other flows and determine their navigability in other craft. On-site reconnaissance also allowed investigation of whitewater characteristics, estimating how those might change as flow levels changed.

Interviews with Resource Experts

Several interviews were conducted with river managers and veteran river runners to help identify trip attributes and specify flow-attribute relationships, as well as to develop the user survey. The interviews were structured to provide information about the various segments of the river at different flow levels. Interviewees were asked to give information about various conditions for different types of craft (rafts, canoes, kayaks). About half of the dozen interviews conducted were completed over the phone.

Figure 19. Measuring channel cross section at La Sal Rapids.

Survey of Experienced Users

A survey of experienced users was the foundation of the recreation component of this study. The survey was developed from the approach used by the BLM instream flow team in the Beaver Creek, San Pedro River, and Gulkana River water right assessment studies (1987, 1988, and 1989 respectively), as well as from an instream flow study conducted on the Colorado River in Grand Canyon (Bishop et al., 1987).

The survey focused on users experienced in boating. Results from previous studies (as noted above) suggest that inexperienced users are generally unable to adequately describe differences in flows, let alone relationships between flows and various trip attributes. The focus on users that boat is justified by the relatively smaller numbers of users that do not boat, but fish, picnic, or camp. In addition, these nonboating uses tend to be less flow-dependent.

The survey sample was generated from lists of users who had expressed interest in the recent BLM river planning process or outfitters currently permitted on the Dolores. The latter group was bolstered by the names of guides who work for the five outfitters who take the most trips on the Dolores each year, obtained over the telephone. In total, 170 users were included in the sample.

Users were mailed the questionnaire and, unless they returned it, received three reminder letters (the third was sent certified mail). In all, 128 users returned the questionnaire, 13 wrote back to say they felt unqualified to answer the survey, and 5 questionnaires were undeliverable (bad addresses). Final response rate was 84 percent.

The survey asked four different sets of questions as described in brief below; the complete survey can be found in Appendix A. The first set focused on user and trip characteristics: type of boat used, number of trips on Dolores, type of user (guide, outfitter, private river boater, etc.). These questions allowed different groups to be analyzed separately.

The second set of questions focused on users' sensitivity to various flow levels when they are planning or taking trips on the Dolores. Questions asked users to note where they obtained flow information and how they used it.

The third set of questions examined flow-attribute relationships and evaluations of flows, asking users to name the flow levels which provide minimum or optimum navigability, whitewater, fishing, or rate of travel conditions. Users were also asked to give an overall evaluation of a range of flows (on a 5-point Likert-type scale ranging from "satisfactory" to "unsatisfactory"). Users were asked to answer all of these questions with respect to a single type of craft, so results could be kept separate.

The final set of questions examined user preferences for various instream flow management goals and specific flow regimes from McPhee Dam. Users were asked to evaluate the potential tradeoffs between a short season with higher flows versus a longer season with lower flows, as well as between optimum fisheries or boating conditions. The flow regime questions asked users to evaluate four different scenarios as either "preferable," "acceptable," or "unacceptable." They were also asked if they would be willing to pay for optimum boating flows if such an arrangement was feasible.

Analysis of the survey generally involved graphic display, descriptive statistics, and tests of significance. Specific analyses are discussed as results are given.

Fish, Wildlife, and Riparian Habitat Methods

A literature search was conducted to develop information on species occurrence, life history, and habitat requirements for fish in the Dolores River system between McPhee Reservoir and Bedrock. Professional biologists knowledgeable about the Dolores River fisheries were also contacted and interviewed.

An analysis of the relationship between low streamflows and habitat availability for brown and rainbow trout was conducted using the Instream Flow Incremental Methodology (IFIM) of the U.S. Fish and Wildlife Service (Bovee, 1982). The IFIM study reach was located approximately 2,000 feet downstream of the pump intake for Dove Creek's water supply system. Six transects were established along approximately 1,200 feet of channel to simulate habitat availability in large and small riffles, pools, and runs or glides (Figures 20, 21, and 22). The study reach selected is representative of the aquatic habitat found in the Dolores River from Bradfield Bridge to the confluence of Disappointment Creek.

Within the study reach, habitat modeling was accomplished using the PHABSIM system of computer programs (Bovee, 1982). Water surface elevations and velocities were simulated at various levels of flow, and the resulting output was coupled with habitat suitability curves for brown and rainbow trout to produce estimates of weighted usable area. Water surface elevations were determined at cross sections without backwater using a Manning's-equation approach (MANSQ program). Water surface elevations at cross sections with backwater effects (i.e., pools) were estimated using a step-backwater approach (WSP program) with starting elevations for the downstream cross-sections supplied from the MANSQ program runs. Velocity calibration was accomplished with the IFG4 program using water surface elevations supplied from the MANSQ and WSP program runs. The habitat simulation program HABTAV analyzed output from the hydraulic programs against habitat suitability curves for brown trout (Raleigh et al., 1986) and rainbow trout (Raleigh et al., 1984) to produce final estimates of weighted usable area.

A computer-based literature search was conducted to recover citations relating to wildlife and riparian habitat on the Dolores River. Several professionals within BLM and Colorado Division of Wildlife were interviewed to gain personal knowledge of wildlife habitat issues associated with the Dolores River below McPhee Reservoir.

The Colorado Wildlife Species Database, an extensive database on the presence, status, taxonomy, geographic distribution, habitat use, life history, and other relevant information on vertebrate species in Colorado, was searched to gain a general idea of the species likely to be present in the Dolores River corridor (Figure 23).

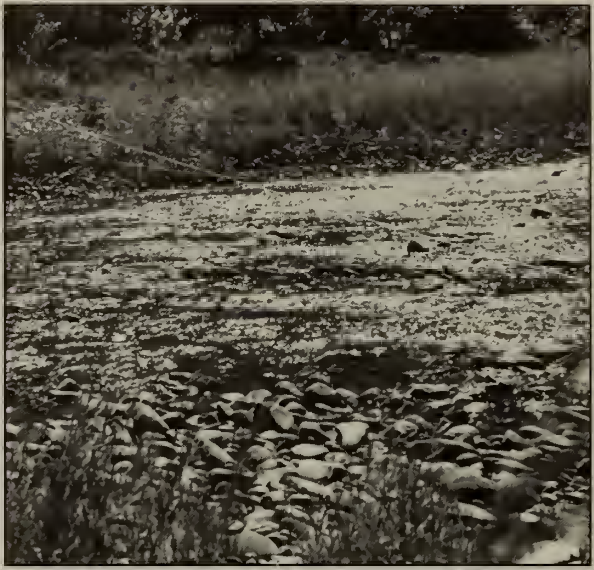


Figure 20. Riffle IFIM transect, Dolores River.

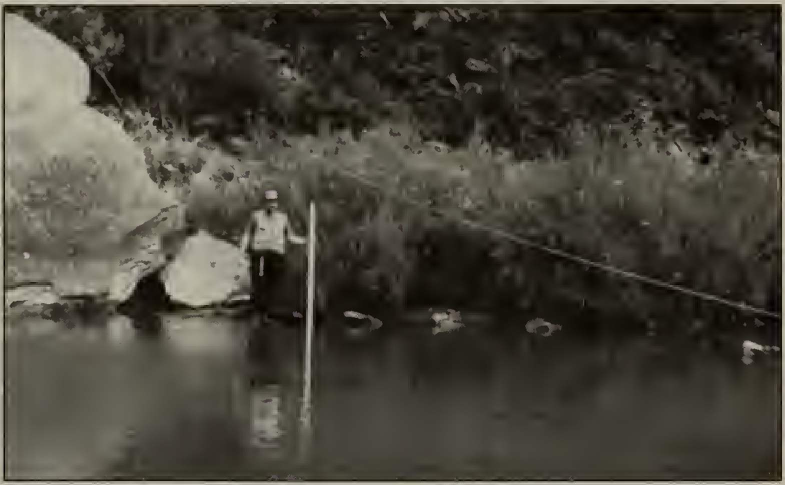


Figure 21. Pool IFIM transect, Dolores River.

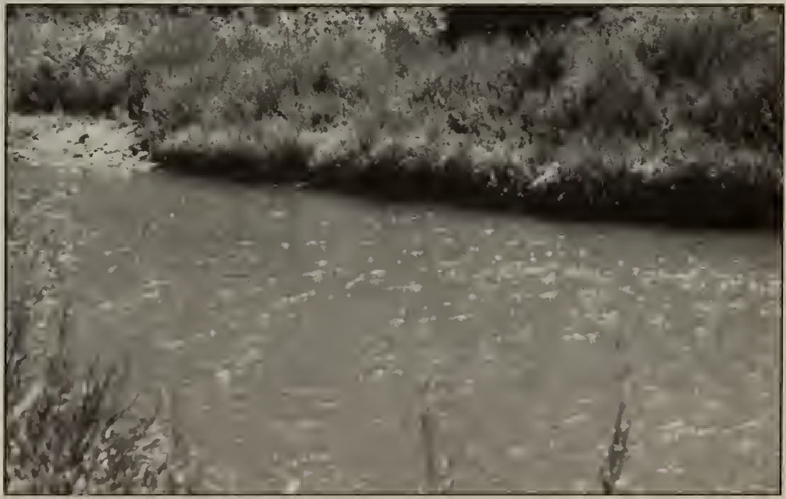


Figure 22. Run (glide) transect, Dolores River.

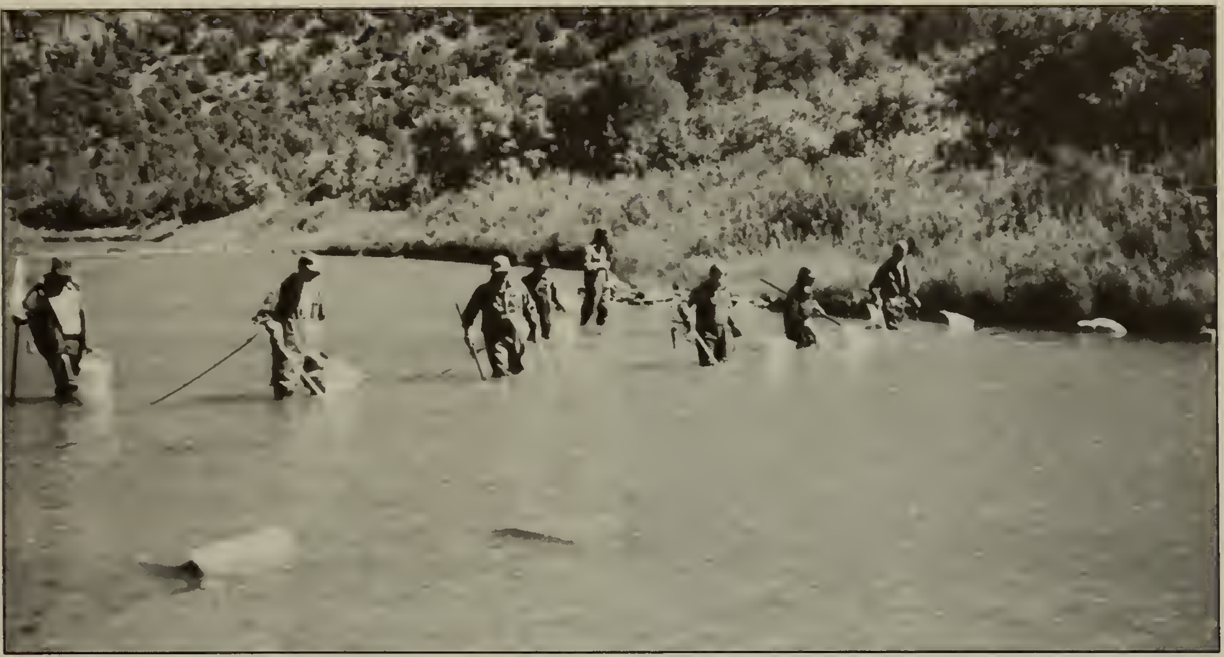


Figure 23. Fish inventory conducted by Colorado Division of Wildlife in conjunction with Dolores River instream flow assessment.

Hydrology and Geomorphology Methods

Hydrologic and geomorphic methods were utilized to address three primary issues: pre- and post-dam hydrology, channel morphology and associated hydraulic-geometry relationships, and sediment transport capacity. These issues were addressed through extensive review and analysis of historic streamflow and water-use records, field measurements of channel morphology and hydraulic geometry, and a combination of field measurements and empirical methods for the analysis of sediment transport characteristics.

Annual hydrographs based on mean monthly flows for the Dolores River below McPhee Reservoir were computed for pre-dam and post-dam conditions. Streamflow gain-loss analyses were completed for the study reach on twice in July, once in August, and once in September 1989. In addition, a flow accounting model was developed under contract to BLM. The model simulates the volume of water that must be released from McPhee Reservoir to meet flow requirements at selected downstream points on the Dolores River. Transects established during field visits serve as the downstream points.

The geomorphic analysis focused on descriptive channel morphology, "at-station" hydraulic geometry relationships (Leopold and Maddock 1953), and principles of stream energy dissipation and channel adjustment. River characteristics studied included channel pattern, longitudinal profile, morphologic features, sediment composition, and both short-term and long-term adjustment processes. Since many geomorphology relationships also depend on sediment yield, sediment transport, and floodplain and riparian conditions, these variables were also factored into the analysis.

For the "at-station" geomorphic analysis, transects were established on the Dolores River near Bradfield Bridge (Figure 24), above Dove Creek Pump Station, above Snaggletooth Rock, at the confluence with Disappointment Creek, below Big Gyp Valley (Figure 25), at the mouths of Bull and Spring Canyons, and above La Sal Creek in the Wilderness Study Area. Flow measurements and photographs were taken at each transect, and channel cross sections were surveyed to end points established at or above bank-full stage. Transect data were analyzed using a Manning's equation approach (Parsons and Hudson 1985), and "at-station" hydraulic geometry relationships were developed between stage and discharge and between discharge and various hydraulic parameters (depth, top width, velocity, cross-sectional area, wetted perimeter, and hydraulic radius).

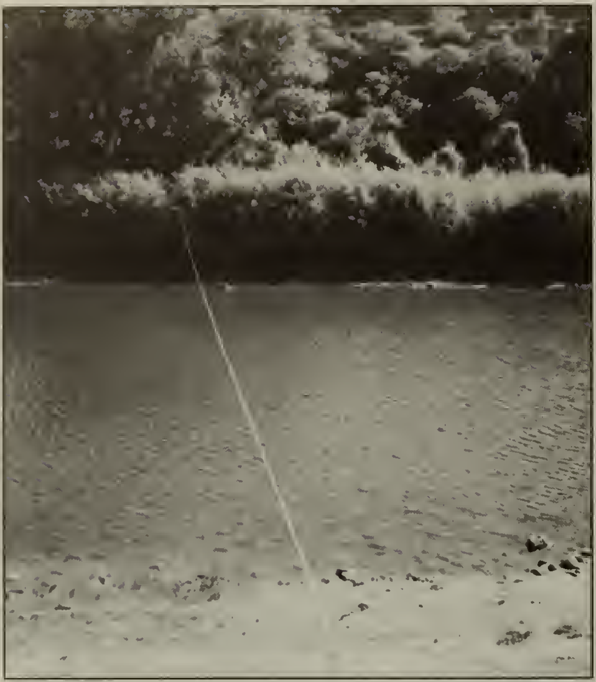


Figure 24. Transect located near Bradfield Bridge, Dolores River.

The use of Manning's equation to develop relationships between stage, discharge, and other hydraulic variables required estimates of water surface slope at streamflows much greater than were encountered during field measurements. The slope of the water surface at high flows is important because it is a measure of the rate of energy expenditure. At low flows, the water surface slope is much steeper in riffle areas than it is in pools. However, as discharge increases, the water surface slope increases through the pool areas and decreases over riffles so that at very high flows, the water surface slope is much more uniform. Thus, for analyzing hydraulic relationships at flows near bank-full, water surface slopes were approximated by the average slope over long stream reaches and were checked against topographic maps for reasonableness.

For analysis of the sediment transport characteristics of the Dolores River, a knowledge of the hydraulic conditions at which bed-material particles begin to move is crucial. The ability to relate the initiation of particle motion to flow conditions is important to the analysis of channel morphology and channel stability. In addition to the development of relationships between discharge and other hydraulic parameters, the rating table developed for each transect was used to estimate average bed shear stress at various levels of high flow. The average bed shear stress is a measure of the forces acting to initiate particle motion on the bed, and is given by:

$$\tau = f R S$$

where τ = average bed shear stress
f = specific weight of water
R = hydraulic radius
S = water surface slope

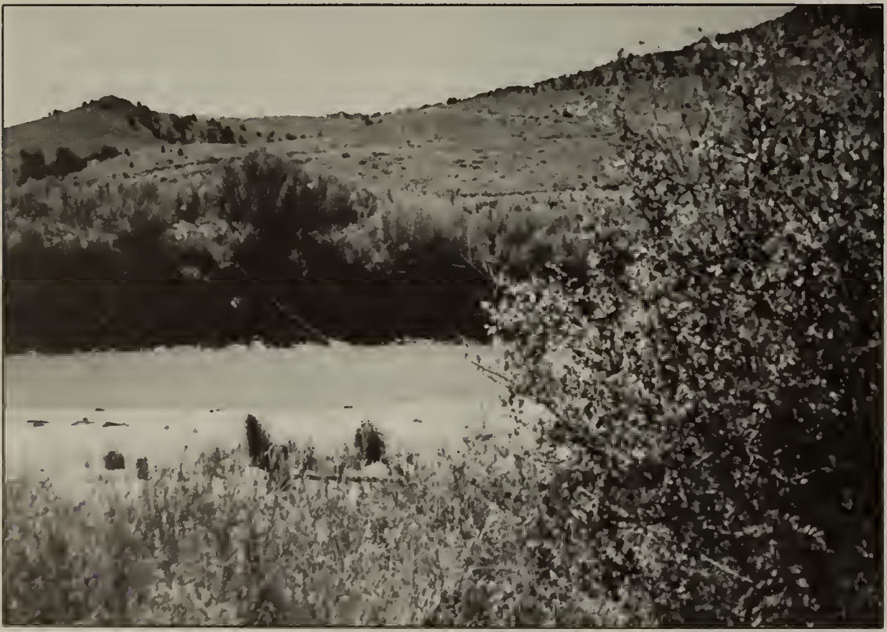


Figure 25. Dolores River transect located below Big Gyp confluence.

The shear stress required to initiate particle motion was estimated from particle-size analysis of bed materials and empirical methods for estimating critical shear stress. Particle size information was obtained from pebble count transects established in several pools and riffles in a critical sediment transport reach near the mouth of Disappointment Creek. The d_{50} and d_{84} particle sizes were determined for each transect. The critical shear stress required to entrain these particle sizes was then estimated using two empirical relations. The equations are described below:

Costa (1983) Method:

$$\tau = 0.163\, d_i^{\,.1213}$$

where d_i = diameter (mm) of the i-th percentile particle size.

Dimensionless Shear Stress Approach (Andrews, 1983):

$$\tau^* = \frac{\tau_i}{(\mu_s - \mu_f)\, d_i}$$

where τ^* = dimensionless shear stress (.030 for d_{50}; .022 for d_{84})

i = shear stress for particle from the i-th percentile

μ_s = specific weight of particle

μ_f = specific weight of water

The critical shear stress obtained from the above equations was then substituted into the equation for average bed shear stress to obtain the hydraulic radius and discharge required to entrain the particle size of interest.

RESOURCE VALUES AND MANAGEMENT OBJECTIVES

Figure 26. Petroglyph discovered on canyon rocks adjacent to Dolores River.

Significant resource values on the Dolores River include outstanding recreational opportunities such as boating and fishing, exceptional aesthetic/ scenic qualities, abundant and diverse wildlife along the river, diverse riparian ecosystems, and important cultural resources (Figure 26). The team determined that the following resource value attributes were flow-dependent.

Recreation Values:

- sufficient water depths to provide a canoe fishing experience
- sufficient water depths and flow velocities to provide a scenic canoe touring experience on both the upper and lower reaches of the river
- sufficient water depths and flow velocities to provide a scenic rafting experience
- sufficient water depths and flow velocities to provide a minimum whitewater rafting and kayaking experience
- sufficient water depths and flow velocities to provide an optimum whitewater rafting and kayaking experience
- sufficient water depths and wetted perimeter to provide for high-quality bank fishing

Fish/Wildlife Values:

- clean substrate for trout spawning
- sufficient depths and wetted perimeter to support brown and rainbow trout throughout their life history

Channel Morphology Values:

- maintenance of channel form (single-threaded channel) and function (especially sediment transport capacity)
- maintenance of sand and gravel bars (lateral and point bars) through periodic scouring and rejuvenation
- sufficient water table elevation to support riparian vegetation communities

These resource value criteria are further defined below.

Water-Based Recreation

There are a variety of recreation opportunities available on the Dolores River (Figure 27). While many users take trips through both the upper and lower canyons, a significant majority only travel through one canyon or the other on any particular trip. In either case, the two canyons provide different resource values or trip attributes, and it is useful to describe them separately.

The following discussion briefly outlines the recreation opportunities available on the Dolores through each of the two canyons and describes the most significant attributes of trips in each canyon. Most of the material in this section is based on results from a 1988 survey of users conducted by Arizona State University in cooperation with the BLM Colorado State Office and the draft river management plan prepared by the San Juan Resource Area of the Montrose District. Readers interested in more detailed information about recreation opportunities, user and trip characteristics, and trip attributes are

Figure 27. Departing campsite in lower reach of the Dolores River.

urged to consult the survey report and the draft management plan.

Upper Canyon

Floating trips through the upper canyon begin at Bradfield Bridge and typically travel through the Dove Creek-Snaggletooth Rapid area and take out at Slickrock. This trip typically lasts 3 days. It is also possible to launch or take out at the Dove Creek Pump Station, thus providing other trips of varying lengths. Those not particularly interested in the more difficult whitewater below Dove Creek will often take out at the Pump Station, while whitewater enthusiasts can utilize the primitive road along the river from Dove Creek to Snaggletooth Rapid for short day trips. The run from Bradfield Bridge to Dove Creek can be made in 1 long day, while the run from Dove Creek to Snaggletooth takes only a few hours. The run from Dove Creek to Slickrock takes 1 long day.

The 1988 survey asked users to rate various reasons for visiting the river. Combining these results with resource reconnaissance information suggests a list of trip attributes summarized in Table 11.

The most basic trip attribute on the upper canyon is *floatability*. Users expect and require certain flow levels which provide a good channel and thus do not require a significant number of portages to get around riverwide bars or other obstacles. While users may still take trips when flow levels do not provide optimum floatability conditions, they clearly prefer to be able to fully float the river.

Another basic trip attribute is *whitewater*. The upper canyon of the Dolores is one of the "classic" whitewater runs in the Southwest, offering long stretches of Class II rapids, several Class III rapids, and one well-known Class IV drop, Snaggletooth Rapid. The 1988 user survey found that "thrills," "developing skills," and "getting exercise" were among the highest ranking "desired experiences," each of which relate to running whitewater. In addition, "running rapids" was among the highest rated activities.

Experienced users (for the whole river) were asked in the 1989 survey which particular whitewater characteristics were most important, and the answers differed slightly for users in different types of craft. While kayakers and rafters ranked large waves as most important, open canoeists preferred long stretches of rock dodging. Other important characteristics for all boaters were large holes or hydraulics and boulders to avoid in the middle of steep drops. Walls at the end of chutes were considered the least important feature for all boaters.

Rate of travel is another flow-related attribute. The upper canyon has a relatively steep gradient, and rate of travel is fairly swift through most of the canyon at many flow levels. Users expect trips to fit into traditional vacation periods (usually 2 or 3 days) and allow plenty of time for camping, fishing, or exploring the canyon.

Scenery, general river aesthetics, and being in a *natural or wildernesslike setting* are three other key trip attributes. The upper canyon features stunning views of mixed ponderosa pine forest, pinyon-juniper woodlands, and towering slickrock walls and pinnacles. Boaters clearly enjoy these views, and they alone provide a compelling reason to visit the river. In the 1988 survey, users rated scenery as the number one "experience desired" and "viewing scenery" as the most important activity. Other highly ranked experiences and activities which are related to

Table 11. Summary of Flow-Related Trip Attributes

Floatability

- good channel for floating
- few portages due to riverwide obstacles

Whitewater

- standing waves
- large boulders/drops
- many rocks to dodge
- hydraulics

Rate of Travel

- reasonable rate

Scenery/General River Aesthetics/Natural Setting

- open banks for views
- geological processes
- natural processes in evidence
- natural vegetation patterns
- few traces of use

Camping

- scenic views of river
- open and flat areas for tents
- proximity to river
- isolation from other camps
- eddies for easy takeouts

Hiking

- access to side canyon trails

Fishing

- variety and abundance of fish
- open areas for casting

scenic values include "observing streamside vegetation," "learning about wildlife," "learning about geology," "birdwatching," and "using sandy beaches." Taken together, these results suggest that users are interested in all of the natural processes associated with the river environment, particularly vegetation and geologic processes, and that they are less interested in human-modified features. Resource reconnaissance indicates that traces of human use are low in the canyon, and this certainly contributes to the natural appearance there.

Trips in the upper canyon also feature *camping*. The overwhelming majority of boaters camp while on the river (99 percent according to the 1988 user survey, although BLM estimates suggest this number is high), and quality camping attributes are certainly important to users. Resource reconnaissance suggests that typical upper canyon camping sites feature good scenic views of the river, open and flat areas for tents and "kitchens," close proximity and good access to the river, isolation from other camps, and good eddies for easy launching.

Other attributes which are important but are likely to be less dependent on flow include *hiking* both along the river and in side canyons (often to explore *cultural resources*), and *fishing*. The latter activity, while engaged in by a relatively small minority of users at present, has the potential to become increasingly important as the developing trout fishery improves and users learn of the opportunity.

Lower Canyon

Floating trips through the lower canyon typically begin at Gypsum Bridge and end at Bedrock (Paradox Valley). There are no shorter trips, although it is, of course, possible to extend the trip by floating from the upper canyon through Slickrock, which includes the 12-mile stretch through Gypsum Valley. The Gypsum Bridge to Bedrock trip takes approximately 3 days.

The 1988 survey asked users to rate various reasons for visiting the lower canyon. Combining these results with resource reconnaissance information suggests a number of trip attributes, most of which are similar to those given for the upper canyon, as listed below.

As in the upper canyon, *floatability* remains the most basic flow-dependant attribute of trips through the lower canyon. Users require a good channel to float down, and prefer not to portage frequently because of low water.

Whitewater is important, but not nearly as important as in the upper canyon. The lower canyon does not have nearly as many challenging rapids as the upper canyon, and has many long stretches of flat water. While users still appear to value the available whitewater, it ranks significantly less important in the 1988 user survey.

Rate of travel is an important trip attribute, as users expect trips to fit into traditional vacation periods. However, most users recognize that the gradient is less in the lower canyon and that rate of travel will be slower there than in the upper canyon, and they probably plan for this.

The variety of attributes associated with *scenery, general river aesthetics*, and being in a *natural or wildernesslike setting* are again important, perhaps even more important than in the upper canyon. The scenery in the lower canyon features even more massive and spectacular slickrock formations, as well as pinyon-juniper woodlands. Evidence of human use is even less obvious. The most common differentiation between the upper and lower canyons focuses on scenery and wilderness qualities. Most users report that the lower canyon provides a more remote, scenic-oriented trip, while the upper canyon provides a more thrilling whitewater trip that also features good scenery. The BLM also recognizes these differences in its management plan, providing for lower use levels and smaller group sizes in the lower canyon, presumably to increase remoteness, solitude, and wildernesslike attributes of the experiences there.

Camping attributes in the lower canyon are similar to those for the upper canyon (Figure 28). High quality sites possess good places to set up tents and "kitchens," good boat launching eddies, and close access and proximity to the river. It is interesting to note that a few sites in the lower canyon may be losing good access as vegetation (particularly tamarisk and poison ivy) increases. A particular flow-dependent issue thus may be whether natural flushing flows clean out such vegetation and enhance camping experiences.

Other potentially flow-related trip attributes include *hiking, visiting cultural resources*, and *fishing*. Hiking in the lower canyon is almost exclusively focused on access to side canyon trails, which are extremely popular among users. Cultural resource sites are also very important to many lower canyon users, as resources there are significantly more abundant than in the upper canyon. Fishing, on the other hand, is generally far less important for lower canyon users than for upper canyon users. The lower canyon does not have any trout, and fishing for native species is clearly a less popular activity. However, there is some demand for catfish fishing.

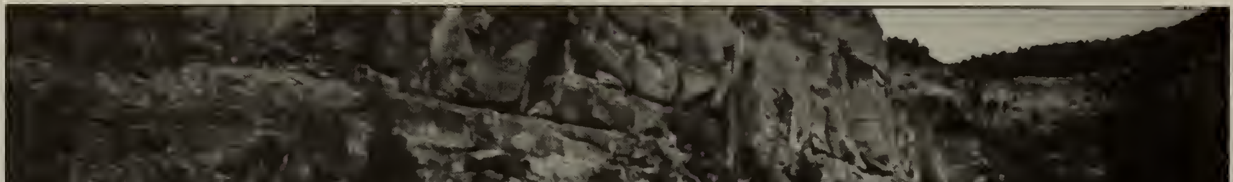


Figure 28. Camping on sand bar located downstream of Coyote Creek Confluence with the Dolores River.

Fishery Habitat Characteristics and Requirements

The Dolores River from McPhee Reservoir to its confluence with Disappointment Creek is developing into a good rainbow trout and brown trout fishery (Figure 29). At the confluence with Disappointment Creek, the fishery begins to change to a warm-water fishery with species such as channel catfish (Japhet, 1989). Scattered through the entire system are a variety of nongame species, many of which are endemic (native) to the river. Recent Colorado Division of Wildlife (CDOW) survey records indicate the following species are present in the Dolores River from Bradfield Bridge to Bedrock (the study reach):

1. Rainbow trout (*Oncorhynchus mykiss*)*
2. Brown trout (*Salmo trutta*)*
3. Snake River cutthroat trout (*Oncorhynchus clarki subsp.*)*
4. Green sunfish (*Lepomis cyanellus*)*
5. Red shiner (*Notropis lutrensis*)*
6. Roundtail chub (*Gila robusta*)
7. Speckled dace (*Rhinichthys osculus*)
8. Common carp (*Cyprinus carpio*)*
9. Fathead minnow (*Pimephales promelas*)*
10. Channel catfish (*Ictalurus punctatus*)*
11. Flannelmouth sucker (*Catostomus latipinnis*)
12. Bluehead sucker (*Catostomus discobolus*)
13. Black bullhead (*Ictalurus melas*)*
14. Yellow bullhead (*Ictalurus natalis*)*
15. Mottled sculpin (*Cottus bairdi*)

* Introduced species

Historical flows and fish species were somewhat different before human impacts. Mining, water diversions, road construction, channelization, and introduction of nonnative fish species in the river have altered the habitat and species composition. At one time the Dolores River was considered a good trout fishery from its headwaters to Slick Rock and possibly provided habitat in the lower reach for three endangered species - the humpback sucker, the bonytailed chub, and the Colorado squawfish.

Streamflows in the Dolores River (McPhee Reservoir to its confluence with Disappointment Creek) are regulated by the Bureau of Reclamation's operation of McPhee Reservoir. The CDOW has applied the IFIM instream flow methodology to 11

Figure 29. Trout makes up part of Dolores River Fishery.

miles of river immediately below McPhee Reservoir. This assessment produced a flow recommendation of 150 ft^3/s yearlong, excluding high flows during spring runoff, to provide for a maximum adult population of rainbow and brown trout (Japhet, 1989). No previous aquatic habitat evaluations have been conducted on Public Lands by the Bureau of Land Management or other agencies (state or Federal).

For the purpose of this report the following species will be emphasized because of their sportfishing value, being endemic to the river, or the amount of available information: 1) rainbow trout, 2) brown trout, 3) channel catfish, 4) roundtail chub, 5) flannelmouth sucker, 6) bluehead sucker, and 7) mottled sculpin.

Rainbow Trout

Optimal rainbow trout riverine habitat is characterized by clear, cold water; a silt-free rocky substrate in riffle-run areas; an approximately 1:1 pool-to-riffle ratio, with areas of slow, deep water; well-vegetated streambanks; abundant instream cover; and relatively stable water flow, temperature regimes, and streambanks (Raleigh et al., 1984). CDOW netting efforts found rainbow trout to exist in the Dolores River upstream from Disappointment Creek.

Rainbow trout can be divided into two ecological forms — anadromous steelhead trout and resident stream trout — with the latter being found in the Dolores River. They are spring spawners and spawn almost exclusively in streams. Spawning probably starts sometime in la te April or early May and may take place as late as the end of June.

Females normally select a redd site in gravel substrate at the head of a riffle or downstream edge of a pool (Orcutt et al., 1968). The redd pit, constructed primarily by the female, is typically longer than the female and deeper than her greatest body depth (Greely, 1932). Egg deposition averages 15 cm (Hooper, 1973). Incubation time varies inversely with temperature. Eggs usually hatch within 28 to 40 days (Cope, 1957). Raleigh et al. (1984) list optimal spawning gravel conditions to include ≤5 percent fines; ≥30 percent fines are assumed to result in low survival of embryos and emerging sac fry. Optimal spawning substrate averages 1.5 to 6.0 cm for rainbows ≤50 cm long and 1.5 to 10 cm for spawners ≥50 cm long (Orcutt et al., 1968).

As with any salmonid, there is a definite link between the annual flow regime and the quality of habitat. The most critical period is during base flow. A base flow ≥50 percent of the average annual daily flow is considered excellent for maintaining quality habitat, 25 to 50 percent is considered fair, and <25 percent is considered poor (Binns and Eiserman, 1979). Raleigh et al. (1984) state that optimal water velocity above rainbow trout redds is between 30 and 70 cm/s. Velocities less than 10 cm/s or greater than 90 cm/s are unsuitable.

Rainbow trout fry remain in the gravel for about 2 weeks before emerging. As they move to rearing areas they exhibit three movement patterns:

1. movement downstream to a larger river or lake
2. movement upstream from an outlet river to a lake
3. local movement within a common spawning and rearing area to areas of low velocity and cover (Raleigh and Chapman, 1971)

Fry require shallower water and lower velocities than at other stages of the trout life cycle (Horner and Bjornn, 1976). Fry utilize velocities less than 30 cm/s, but velocities less than 8 cm/s are preferred (Griffith, 1972).

Rainbow trout fry overwinter in shallow areas of low velocity, with rubble being the principal cover (Bustard and Narver, 1975). Optimal size substrate ranges from 10 to 40 cm in diameter (Hartman, 1965). In some streams, the major factor limiting salmonid densities may be the amount of adequate overwintering habitat, rather than the amount of summer rearing habitat (Bustard and Narver, 1975).

Cover is an essential component in trout streams, and to a large extent determines the stream's carrying capacity. It can be found in two forms: (1) bank cover (vegetation) and (2) instream cover (substrate, turbulence, etc.). Wesche (1980) reports that areas of obscured stream bottom with water ≥15 cm deep and velocities of ≤ 15 cm/s will provide important cover. Cover of ≥ 25 percent of the total stream area provides adequate cover for adult trout (Raleigh et al., 1984).

Adult and juvenile rainbow trout are opportunistic feeders. Their diets consist mainly of aquatic insects (Allen, 1969), but foods such as zooplankton (McAfee, 1966), terrestrial insects, and fish are locally or seasonally important (Carlander, 1969). The relative importance of aquatic and terrestrial insects to resident stream rainbow trout varies greatly among different environments, seasonally and diurnally, and with the age of the trout (Bission, 1978).

Brown Trout

Raleigh et al. (1986) identify optimal brown trout habitat as "clear, cool to cold water; a relatively silt-free rocky substrate in riffle-run areas; a 50 to 70 percent pool to 30 to 50 percent riffle-run habitat combination with areas of slow, deep water; well vegetated, stable streambanks; abundant instream cover; and relatively stable annual water flow and temperature regimes." Basically, brown trout occupy reaches of low to moderate gradient (<1 percent) in suitable, high gradient river systems. Random netting by the CDOW indicate brown trout make their appearance in the Dolores River below Slick Rock and exist upstream.

Brown trout are fall spawners. Frost and Brown (1967) found that migration to locate suitable spawning sites began when water temperatures reached 6 to 7 °C. Mansell (1966) found that spawning occurs at 7 to 9 °C. Spawning sites are generally found at the head of a riffle or at the tail of a pool and have well defined redds. Reiser and Wesche (1977) found brown trout to prefer gravel with a diameter of about 1 to 7 cm for spawning, with the maximum size related to the size of the spawning female. Optimal spawning gravel conditions are assumed to be ≤ 5 percent fines. Allen (1951) found the size of redds varied in width from <30 cm to >107 cm. For the Dolores River, spawning can take place as early as mid-September to as late as early November.

The quality of brown trout habitat and the flow regime is closely related, with late summer to spring being the most critical period. Flows have to be high enough to meet the needs of developing embryos (prevent winter freezing) but not high enough to allow destructive movement of the substrate. A base flow ≥ 50 percent of the average annual daily flow regime produces quality brown trout habitat. Waters (1976) found optimal water depths for brown trout at redd sites to be 24.4 to 45.7 cm, with a suitable range of 12.2 to 91.4 cm. Water velocities of 53.3 to 68.6 cm/s produce optimal habitat, with a range of 15.2 to 91.4 cm/s being suitable for spawning. Shirvell and Dungey (1983) found that velocity was more important than depth as a selection criterion for spawning, with a mean of 39.4 cm/s being the preferred velocity.

Like any salmonid, dispersal of fry takes place immediately after emergence. Mills (1971) found brown trout fry to be aggressive and territorial, and that they distributed themselves to suitable habitat within a week. Wesche (1980) found that both fry and juvenile brown trout prefer shallower depths and velocities <15 cm/s, while adults prefer depths ≥ 15 cm and a focal point of <15 cm/s for resting and feeding.

Cover is essential to adult brown trout as well as juveniles for survival. Examples of cover important to brown trout include such items as instream and streambank vegetation, undercut banks, woody debris, substrate, pool depth, and surface turbulence. Raleigh et al. (1986) found a cover area of ≥ 35 percent of the total stream area provides adequate cover for adults, while ≥ 15 percent of total stream area is adequate for fry and juveniles. During winter months particle size of 10 to 40 cm provides excellent cover for fry and small juveniles (Everest, 1969). Adults tend to move into deeper, slower-moving water during the winter.

Brown trout are categorized as size-selective feeders, preferring larger prey (Ringler, 1979). Generally they feed on terrestrial and aquatic insects until they exceed 25.0 cm in length and then switch to fish and crustaceans (Hannukula, 1969).

Channel Catfish

McMahon and Terrell (1982) list optimum riverine habitat for channel catfish as having warm temperatures and a diversity of velocities, depths, and structural features that provide cover and food. Habitat suitability is greatly influenced by spawning requirements, with nesting cover playing a significant part (Marzolf, 1957). Nettings by CDOW show that channel catfish first occur in the Dolores River around the Mucho Grande Mine (river mile 136), and are then found downstream through the remainder of the study reach.

Channel catfish are late spring spawners and probably spawn in the Dolores River starting near the end of May and continuing through mid-July. This usually takes place when temperatures reach about 21 °C (Marzolf, 1957). Byran et al. (1975) found that catfish in large rivers move to shallow, flooded areas to spawn. The males build and protect the nest that can be found in cavities, in burrows, under rocks, or in other protected areas (Pflieger, 1975). The optimum temperature for embryo development is 27 °C, with a range of 15.5 to 29.5 °C (Brown, 1942).

Cover is important to fry, juveniles, and adults, but data listing cover requirements are limited. Bailey and Harrison (1948) found channel catfish prefer areas of deep pools and backwaters with velocities <15 cm/s. Boulders, debris, and logs seem to provide important overwintering habitat (Miller, 1966). Pools ≤5 m deep with ≥40 percent suitable cover provide optimum habitat (McMahon and Terrell, 1982). Davis (1959) found fry to aggregate near cover in slow-flowing areas (rocky riffles, gravel bars, etc.) at velocities <15 cm/s.

Adult channel catfish are opportunistic feeders. Their diet includes terrestrial and aquatic insects, plant material, crayfish, mollusks, and even fish when >50 cm in length (Starostka and Nelson, 1974). Bottom feeding is the norm for channel catfish, but food is taken throughout the water column. Fry are predominantly plankton and aquatic insect feeders.

Areas (riffles, runs) with velocities <15 cm/s and with debris and aquatic vegetation, conditions associated with good aquatic insect production, provide excellent feeding sites for channel catfish (Hynes, 1970). Since channel catfish prefer river sections with velocity and structural diversity, it is assumed that riverine habitat with 40 to 60 percent pools is considered optimum for food production (McMahon and Terrell, 1982).

Roundtail Chub

The roundtail chubs are abundant and endemic to the Dolores River. Considered a large-river fish, roundtails prefer slow moving water adjacent to areas of faster water. Small groups then move into the faster water "presumably to feed" (Minckley, 1973). Fry and juveniles have been found to utilize shallow river runs and river eddies. CDOW survey records indicate the roundtail chub is found in the entire study reach of the Dolores River and is commonly found in conjunction with large boulder and cobble substrate in slow-moving water.

Information on habitat requirements is limited, but Minckley (1973) provides the following information:

> Spawning probably takes place over gravel substrate much like other minnows, and occurs in early summer, with females scattering eggs over the substrate, providing no parental care. Adults are considered predators and will take small fish as well as insects and filamentous algae. Fry and juveniles feed on insects and algal films.

Woodling (1985) identifies the roundtail chub as the most common species of *Gila* found in the Colorado River Basin.

Flannelmouth Sucker

Like the roundtail chub, the flannelmouth is endemic to the Dolores River, and CDOW records place this species in the entire study reach. McAda and Wydoski (1976) identify it as the most abundant and widespread native fish in the upper Colorado River Basin. Flannelmouth suckers are large-river fish and have been found in riffles, runs, eddies, and backwaters (Woodling 1985). Flannelmouth suckers are commonly found lower in the drainage in warmer water than the bluehead sucker.

Spawning can take place in early April or as late as June (McAda and Wydoski, 1976). Ripe males and females seem to congregate at upstream points of cobble bars in water about 1 m deep, with flow of about 1 m/s. The actual spawn does not take place over the cobble but probably occurs nearby.

Like most suckers, the flannelmouth is a bottom feeder. Invertebrates comprise most of the diet, but small mollusks and plant material do play a part. Even though they may compete with trout for food, they are beneficial to trout as a forage fish due to their high productive rate.

Bluehead Sucker

The bluehead sucker is endemic to the Dolores River, and survey records indicate their presence in the entire study reach. Woodling (1985) describes preferred habitat as areas of moderate-to-fast velocity waters. Bluehead suckers tend to prefer rock substrate and are commonly found in riffles. In rivers where substrate is composed of sand, they tend to locate where rock shoals created by talus slopes reach into the water. Unlike the flannelmouth sucker, the bluehead sucker is not just a large-river fish. They are found in small headwater streams and large rivers. Like the flannelmouth, the bluehead sucker is a spring to early summer spawner. Not much is known about its breeding habits, but they are probably much like the flannelmouth sucker. The bluehead sucker is a bottom feeder. It feeds on algae, invertebrates, and other material scraped from the substrate. They usually feed in swift water pulling themselves along the bottom. This can occur while they are on their sides as well as upside down. The bluehead sucker is probably a good forage fish for other species found in the Dolores River.

Mottled Sculpin

The mottled sculpin is another endemic nongame species that exists in the Dolores River. Preferred sculpin habitat is interstitial spaces between rocks and cobble (Woodling, 1985) in clear, cool, swift mountain streams and rivers. Because of this preferred habitat site, sculpin can be used as an indicator of habitat quality. Activities that create erosion and discharge of materials like silt or mud result in the reduction of or even the elimination of sculpins from affected reaches. Sculpin are also of value because they serve as a forage fish for trout. Sampling conducted by the CDOW indicates that sculpin can be found in the Dolores River starting around Dove Creek, continuing upstream to the headwaters.

Sculpin are considered spring spawners (end of April to July) and initiate activities when temperatures reach about 10 ^{o}C. A nest site is located under an overhanging rock and the adhesive eggs are attached to the bottom side of the rocks. Males stand guard until the eggs hatch (Woodling, 1985). Their food source is primarily macroinvertebrates with some small fish and crustaceans.

Terrestrial Wildlife and Riparian Vegetation

This section summarizes the dependency of terrestrial wildlife on instream flow in the Dolores River between Bradford Bridge and Bedrock. It is based upon a review of literature and other information (Cooperrider, 1989) and upon a 5-day reconnaissance of the river during May 1989. Existing knowledge of species is summarized by Cooperrider (1989).

Four species have been identified as of particular concern in the area because of limited numbers or habitat or because of their sensitivity to changes in flow regime: great blue herons (*Ardea herodias*), peregrine falcons (*Falco peregrinus*), river otters (*Lutra canadensis*), and bighorn sheep (*Ovis canadensis*).

Great Blue Herons

Great blue herons are protected migratory birds that nest colonially in traditional sites, in mature and old-growth trees, particularly cottonwoods, along riparian areas. They feed upon aquatic animals in shallow water and wet meadows. They nest in the region, but no known colony or suitable habitat for a nesting colony was observed along the stretch of river from Bradfield Bridge to Bedrock. Individual birds undoubtedly forage along the river at times; however, Towery (1984) indicates that foraging sites need to be within 2.5 miles of nesting sites. Therefore, it is unlikely that this stretch of river is a critical foraging area during the crucial nesting season.

Peregrine Falcons

Peregrine falcons are Federally endangered species that nest on cliffs and feed upon a variety of small and medium-size birds. They were extirpated from the region, but have been successfully reintroduced in the last 10 years. A change in flow regimes that caused a reduction in density of Passerine (songbird) and other small and medium-size birds would result in a decreased forage base for this species.

River Otters

River otters are State-protected mammals that are associated with freshwater habitat for all aspects of their life cycle. River otters were extirpated from the area, but were reintroduced in 1988. They feed upon a variety of aquatic animals including fishes and invertebrates. Crayfish comprise a major portion of the otter diet throughout North America (Toweill and Tabor, 1982) and are undoubtedly an important forage base for otters in the Dolores River. Any flow regime that would significantly reduce the aquatic fish and invertebrate biomass in the river could significantly impact the otter population. The reintroduced river otters are being monitored and studied by Mr. Tom Beck of the Colorado Division of Wildlife. Results of these studies may result in future recommendations to BLM on river management to enhance habitat for the otters.

Bighorn Sheep

Desert bighorn sheep (*O. canadensis nelsoni*) are protected game species that utilize steep, rocky, open habitat for escape cover and prefer to forage in or near such habitat. They normally require free water for drinking during the hot summer months, and populations are typically limited by the amount of suitable habitat that contains water, escape habitat, and foraging areas in proximity to each other. Along the Dolores River, escape cover is abundant, but appears to be separated from the best foraging areas, which are on top of the canyon rims where they are subject to intensive livestock grazing. Neither reduced flow nor degradation of riparian vegetation is likely to limit the bighorn sheep on the Dolores River. An extreme increase in recreational use of the river from a modified flow regime possibly could cause detrimental disturbance to the sheep population, but this is somewhat speculative since the habitat requirements and use by this herd are not well understood. A cooperative study of the sheep habitat use and requirements in the canyon was initiated in 1989 by the BLM, Colorado Division of Wildlife, and Colorado State University. Results of that study should provide BLM with necessary information to modify management of the river corridor if necessary.

Riparian Vegetation

Many of the animal species present in the river system are dependent upon woody riparian species for parts of their life cycle. Concern has been expressed that loss of woody riparian species, particularly cottonwoods, may result from the more even flows present since the construction of McPhee Dam. Reconnaissance of the river revealed, however, that the section of river from Bradford Bridge to Bedrock contains very limited cottonwood habitat. Where large trees are present, they are mostly inland boxelder (*Acer negundo*), rather than cottonwood. The lower and more disturbed stretches of the section also contain significant stands of tamarix. The greater proportion of the woody vegetation is shrubs of willow and other species. Any substantial reduction in this vegetation component would undoubtedly reduce the abundance and diversity of the terrestrial fauna.

Other Resource Values Not Flow Dependent

Cultural resources are found throughout the river corridor. Significant cultural resources such as archaeological sites exist within the study area. The value of these resources does not appear to be dependent on streamflow; therefore, resource value-flow relationships were not developed for cultural resources. The potential for cultural-resource degradation would be directly related to river use (number of users per day). An argument could be made that flow levels which optimize river use might also facilitate deterioration of archaeological sites due to heavy use or vandalism.

Management Objectives

BLM has expressed in its Dolores River Corridor Management Plan (BLM, 1990) general as well as reach-specific management objectives for the river corridor. General objectives pertinent to this report include a) maximizing the availability of impounded-water releases for river management opportunities by coordinating with the Dolores Water Conservancy District (and other appropriate entities); b) providing for recreational opportunities in the fall and winter seasons in addition to standard spring/summer activities; and c) identification of limiting factors which may be influencing the opportunity to improve riparian communities. This report will address, either directly or indirectly, each of these objectives.

BLM (1990) also set management objectives on a reach-by-reach basis. Several of these specific objectives address flow-dependent resource values.

Bradfield Bridge to Dove Creek Pump Station

This reach is to be managed to be largely free from the evidence of man, to maintain an environment that offers some degree of risk and challenge (BLM, 1990), and to be consistent with criteria used to recommend "scenic" classification status in the Dolores River Wild and Scenic Rivers Study Report (Colorado Department of Natural Resources, 1976). Specific wildlife and fishery objectives include the management of a reintroduced population of river otters in the upper portion (river miles 168 to 124) of the river, which includes this reach, and the identification of limiting factors which may be influencing the potential for freshwater vertebrates (fish) and macroinvertebrates to establish viable populations.

Dove Creek Pump Station to Disappointment Creek

This reach is to be managed to provide a predominantly natural or naturally appearing environment (BLM, 1990), and to be consistent with criteria used to recommend "scenic" classification status per the Wild and Scenic Rivers Study Report

(Colorado Department of Natural Resources, 1976). Wildlife and fishery habitat management objectives are the same as for the Bradfield Bridge to Dove Creek Pump Station reach.

Disappointment Creek to Gypsum Valley Bridge

This reach is to be managed to provide a naturally appearing environment with the presence of man evident but subordinate to the natural scene, and to be consistent with criteria used to recommend "recreational" classification status per the Wild and Scenic Rivers Study Report (Colorado Department of Natural Resources, 1976). BLM (1990) gave no wildlife or fishery habitat objectives for this reach.

Gypsum Valley Bridge to Bedrock

This reach includes the Dolores River Canyon Wilderness Study Area. The reach is to be managed to be essentially free from the evidence of man and to ensure an environment which offers a high degree of risk and challenge. The management of resources will be dependent upon maintaining natural ecosystems which allow for natural ecological changes. The reach will be managed to be consistent with criteria used to recommend "wild" classification status per the Wild and Scenic Rivers Study Report (Colorado Department of Natural Resources, 1976). BLM (1990) gave no wildlife or fishery habitat objectives for this reach.

BLM (1990) also stated that Executive Order 11988 requires Federal agencies to consider the natural and beneficial values of floodplains potentially affected by their actions, and to use management techniques that minimize degradation, maintain, improve, or enhance resource conditions associated with aquatic/riparian habitat. This report has addressed all of the above specific management objectives with respect to flow-dependent resource values.

ANALYSIS OF WATER MANAGEMENT OPTIONS

Introduction

This section discusses the existing water rights structure governing the use of water from the Dolores River. It provides the legal background necessary to understand the existing use of water in this basin. A second objective of this section is to identify the institutional and market options for increasing streamflows within the study area. A third objective is to describe the legal options for protecting such streamflows.

The Dolores River headwaters are in the San Juan Mountains in southwestern Colorado. Most of the flows in the upper Dolores River result from runoff and snowmelt from this mountainous area. According to stream-gauging records at the town of Dolores, about 33 percent of the total annual runoff occurs during May. About 72 percent occurs during the 3-month period from April through June. Tributaries to the Dolores River within the study area are relatively few in number and low in water yield. Thus streamflows within the study area depend largely on water coming from upstream. Average annual streamflows at the McPhee Reservoir site are 349,000 acre-feet.[1] However, streamflows downstream into the study area are considerably lower than this. Historically, these streamflows have been reduced by diversions of Dolores River water out of the basin by the Montezuma Valley Irrigation Company (MVIC) during the irrigation season. Since 1984, streamflow patterns have been altered by the operation of McPhee Reservoir.

The Dolores River is a fully appropriated river. Opportunities for increasing streamflows within the study area depend on finding ways to reallocate existing uses of the river. This requires an examination of the existing water rights on the Dolores River.

Water Rights on the Dolores River

All water rights were examined to assess available water from the Dolores River and its tributaries down to the confluence with the San Miguel River. Most of the rights in this area involve the use of relatively small quantities of water. One hundred four water rights were identified that (1) use 1 ft^3/s of water or more, and (2) are senior to the rights for McPhee Reservoir and the Dolores Water Conservancy District (DWCD). These rights are listed in Table 12. The earliest appropriation date in the Dolores Basin is 1879. Most of the rights in this area date in the 1800's.

Water use in the Dolores Basin is dominated by a few very large water rights. The most senior of these large rights are Main Canals 1 and 2 and include absolute rights of 707.7 ft^3/s and 100 ft^3/s as well as a conditional right to 592.3 ft^3/s,[2] all with an appropriation date of 1885. These rights are owned by the Montezuma Valley Irrigation Company and are used for irrigation and domestic purposes in the Montezuma Valley. Average annual diversions pursuant to these rights have been about 143,000 acre-feet.[3] These diversions represented approximately 40 percent of the total flows available at this point in the river between the period 1928 to 1973. These diversions take the water totally out of the Dolores River Basin. Thus, they are 100 percent depletive of the river. MVIC also holds absolute storage rights for Narraguinnep, Groundhog, and Totten Reservoirs. These rights are shown in Table 13.

The other major water rights in this section of the Dolores River are held by the DWCD (see Table 14). These rights have an appropriation date of 1940 and were adjudicated in 1963.

The major feature of the Dolores Project is McPhee Dam and Reservoir. The reservoir has a capacity of 381,100 acre-feet. The primary use of project water will be for irrigation supply. This includes an annual average supplemental irrigation supply of 13,700 acre-feet to the existing MVIC system to irrigate 26,300 acres of land. An average annual full service irrigation supply of 54,300 acre-

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[1] Definite Plan Report, p. 65.

[2] A major portion of the conditional water right has been transferred to the Dolores Water Conservancy District. See text accompanying footnote 5.

[3] Definite Plan Report, p. 66.

Table 12. Water Rights of 1 ft³/s or More

Structure	Source	Quantity	Abs/Cond.	Priorlty
1. Dolores Water Diversion	Dolores River	1 ft³/s	Absolute	5-18-79
2. Main Canal No. 1	Dolores River	1.1 ft³/s	Absolute	5-31-79
3. Illinois Ditch	Dolores River	3.9 ft³/s	Absolute unquantified	4-15-80 Conditional
4. Main Canal No. 1	Dolores River	1.1 ft³/s	Absolute	4-15-80
5. Home Ditch	Dolores River	2.0 ft³/s	Absolute unquantified	5-01-80 Conditional
6. Italian Ditch	Dolores River	1.0 ft³/s	Absolute	5-01-80
7. Moriarity Ditch	East Fork Dolores	1.0 ft³/s	Absolute	12-31-80
8. Burch and Longwell Ditch	Dolores River	1.0 ft³/s	Absolute	4-30-81
9. DD Williams Ditch	Dolores River	1.0 ft³/s	Absolute unquantified	5-01-81 Conditional
10. Main Canal No. 2	Dolores River	1.0 ft³/s	Absolute	5-01-81
11. Hammond and Clark Ditch	Dolores River	1.0 ft³/s	Absolute	5-10-81
12. Lone Dome Ditch	Dolores River	1.0 ft³/s	Absolute	2-20-82
13. Stevens or Riley Watson*	West Paradox Cr.	1.75 ft³/s	Absolute	7-09-81
14. Gould and Moriarity Ditch	East Fork Dolores	4.0 ft³/s	Absolute unquantified	5-15-82 Conditional
15. Main Canal No. 1	Dolores River	1.0 ft³/s	Absolute	5-15-82
16. Royce and Risley Ditch	Lost Canyon	1.0 ft³/s	Absolute	7-22-82
17. Sebastian Tam Ditch	Dolores River	1.0 ft³/s	Absolute unquantified	5-31-83 Conditional
18. Main Canal No. 1	Dolores River	1.0 ft³/s	Absolute	5-31-83
19. Galloway Ditch*	West Paradox Creek	1.0 ft³/s	Absolute	5-31-83
20. Galloway Ditch*	West Paradox Creek	1.0 ft³/s	Absolute	5-31-84
21. Monument Rock Ditch	East Fork Dolores	2.0 ft³/s	Absolute unquantified	6-01-85 Conditional
22. Main Canal No. 1	Dolores River	707.7 ft³/s	Absolute 87.3 ft³/s	11-25-85 Conditional
23. Turkey Creek Ditch	Lost Canyon	30.0 ft³/s	Absolute unquantified	7-16-86 Conditional
24. Robinson Ditch*	West Paradox Creek	3.0 ft³/s	Absolute	9-30-86
25. Wattles and Freeman Ditch	Turkey Creek	3.5 ft³/s	Absolute unquantified	9-20-88 Conditional
26. DD Williams Ditch	Dolores River	1.0 ft³/s	Absolute	1-10-91
27. Lyons Ditch	East Fork Dolores	1.0 ft³/s	Absolute unquantified	4-30-91 Conditional
28. Lone Dome Ditch	Dolores River	1.2 ft³/s	Absolute unquantified	4-04-91 Conditional
29. Italian Ditch	Dolores River	1.0 ft³/s	Absolute	6-12-91
30. Burch and Longwill Ditch	Dolores River	2.0 ft³/s	Absolute unquantified	6-17-91 Conditional

Table 12. Water Rights of One ft³/s or More (continued)

Structure	Source	Quantity	Abs/Cond.	Priority
31. Hammond and Clark Ditch	Dolores River	3.6 ft³/s	Absolute unquantified	6-17-91 Conditional
32. Moriarity Ditch	East Fork Dolores	2.8 ft³/s	Absolute unquantified	6-18-91 Conditional
33. Keystone Ditch	Dolores River	1.4 ft³/s	Absolute	6-24-91
34. Red Rock Ditch	Taylor Creek	1.0 ft³/s	Absolute	2-01-92
35. Quarry No. 1 Ditch	East Fork Dolores	6.5 ft³/s	Absolute	2-01-92
36. Koenig Ditch	West Fork Dolores	4.0 ft³/s	Absolute	2-01-92
37. Rogers Ditch	Fish Creek	3.0 ft³/s	Absolute	2-01-92
38. East Eder Ditch	West Dolores River	1.0 ft³/s	Absolute	2-01-92
39. Leavensworth Ditch	Fish Creek	3.0 ft³/s	Absolute	2-01-92
40. East Eder Ditch	West Dolores River	8.5 ft³/s	Absolute	2-01-92
41. Goebel Ditch	West Dolores Rvr.	10.2 ft³/s	Absolute	2-01-92
42. Jessee Love Ditch	West Dolores River	6.0 ft³/s	Absolute	2-01-92
43. West Eder Ditch	Fish Creek	7.0 ft³/s	Absolute	2-01-92
44. Narraguinnep Reservoir	Dolores River	5,969 acre-ft	Absolute	2-01-92
45. Keystone Ditch	Dolores River	2.0 ft³/s	Absolute	2-01-92
46. King No. 2 Ditch	groundwater	1.66 ft³/s	Absolute	2-01-92
47. Ortiz Ditch	Dolores River	1.0 ft³/s	Absolute	2-01-92
48. Bradfield Ditch	Dolores River	1.5 ft³/s	Absolute	2-01-92
49. King No. 1 Ditch	Roaring Forks Creek	4.2 ft³/s	Absolute	2-01-92
50. McEwen Ditch	Fish Creek	4.1 ft³/s	Absolute	6-01-94
51. Linstrom Ditch	East Fork Dolores	4.5 ft³/s	Absolute	12-31-94
52. Knoblock Ditch	Stoner Creek	1.5 ft³/s	Absolute	3-21-96
53. Roubidoux Ditch	East Fork Dolores	3.25 ft³/s	Absolute	8-15-99
54. Rieva Ditch	West Dolores River	5.0 ft³/s	Absolute	3-21-1900
55. Garbarino No. 1 Ditch	West Dolores River	1.75 ft³/s	Absolute	12-31-00
56. Garbarino No. 2 Ditch	West Dolores River	2.0 ft³/s	Absolute	12-31-00
57. Garbarino No. 3 Ditch	West Dolores River	1.0 ft³/s	Absolute	12-31-00
58. Italian Ditch	Dolores River	1.0 ft³/s	Absolute	4-01-03
59. Sheek Ditch	Dolores River	2.0 ft³/s	Absolute	4-15-03
60. Stoner Creek Ditch	Stoner Creek	1.0 ft³/s	Absolute	4-01-04
61. AM Puett Reservoir	Lost Canyon	264 acre-ft 390 acre-ft	Absolute Conditional	11-28-04
62. AM Puett Reservoir	Lost Canyon	1,666 acre-ft	Conditional	3-01-05
63. Summit Reservoir	Lost Canyon	3,013 acre-ft unquantified	Absolute Conditional	3-01-05
64. Groundhog Reservoir	Groundhog Creek	10,623 acre-ft unquantified	Absolute Conditional	8-01-05

Table 12. Water Rights of One ft³/s or More (continued)

Structure	Source	Quantity	Abs/Cond.	Priority
65. Rossi Ditch	West Dolores River	1.25 ft³/s	Absolute	12-31-06
66. Totten Reservoir	Dolores River	400 acre-ft	Absolute	4-25-07
67. Big Pine Reservoir	Lost Canyon	459.19 acre-ft unquantified	Absolute Conditional	5-16-07
68. Summit Reservoir	Lost Canyon	154.79 acre-ft	Alt.Div.Pt.	5-16-07
69. Narraguinnep Reservoir	Dolores River	3,306 acre-ft	Absolute	10-28-07
70. Amended Laura Ditch*	West Paradox Creek	2.0 ft³/s	Absolute	3-28-11
71. Swain Ditch Extension*	West Paradox Creek	2.0 ft³/s	Absolute	3-28-11
72. Ray Ditch*	West Paradox Creek	2.83 ft³/s	Absolute	3-28-11
73. Galloway Ditch*	West Paradox Creek	2.13 ft³/s	Absolute	3-28-11
74. South Midway Ditch*	West Paradox Creek	2.57 ft³/s	Absolute	3-28-11
75. Ray Ditch*	West Paradox Creek	22.17 ft³/s	Absolute	3-28-11
76. McEwen Ditch	Fish Creek	4.1 ft³/s	Absolute	6-01-11
77. South Midway Ditch*	West Paradox Creek	15.33 ft³/s	Absolute	3-14-12
78. Goshorn Ditch*	West Paradox Creek	3.5 ft³/s	Absolute	3-01-15
79. Galloway Ditch*	West Paradox Creek	7.5 ft³/s	Absolute	3-01-15
80. Lawrence E. Rogers Ditch	Dolores River	1.5 ft³/s	Absolute	4-01-19
81. Narraguinnep Reservoir	Dolores River	11,527 acre-ft	Absolute	8-17-22
82. Chuck Wagon Well	Dolores River	1.0 ft³/s unquantified	Absolute Conditional	7-21-1924
83. Beaver Ditch	Beaver Ditch	150.0 ft³/s	Conditional	10-24-29
84. Groundhog Reservoir	Groundhog Creek	11,086 acre-ft unquantified	Absolute Conditional	10-24-29
85. Carter Ditch	East Fork Dolores	4.12 ft³/s	Absolute	6-01-30
86. Riverside Ditch	East Fork Dolores	2.6 ft³/s	Absolute	6-08-31
87. Bear Creek Ditch	Bear Creek	10.6 ft³/s	Absolute	12-18-33
88. Frank Robinson Ditch	East Fork Dolores	1.74 ft³/s	Absolute	12-18-33
89. Burch and Longwill Ditch	Dolores River	4.0 ft³/s	Absolute	12-18-33
90. Starrett Ditch	East Fork Dolores	2.3 ft³/s	Absolute	12-18-33
91. Starrett Ditch	East Fork Dolores	2.0 ft³/s	Absolute	12-18-33
92. Dolores Water Divr Hgt	Dolores River	10.0 ft³/s	Absolute	12-18-33
93. Main Canal No. 1	Dolores River	90.0 ft³/s	Absolute	12-18-33
94. Moriarity Ditch	East Fork Dolores	3.2 ft³/s unquantified	Absolute Conditional	12-18-33
95. Unnamed Ditch or P-L	Priest Gulch	1.302 ft³/s	Absolute	12-18-33
96. Gould and Moriarity Ditch	East Fork Dolores	2.0 ft³/s	Absolute	12-18-33
97. Turkey Creek Ditch	Lost Canyon	60.0 ft³/s	Absolute	12-18-33
98. Summit Ditch	Lost Canyon	135 ft³/s	Absolute	12-18-33
99. Tenderfoot Ditch	Tenderfoot Creek	2.56 ft³/s	Absolute	12-18-33

Table 12. Water Rights of One ft³/s or More (continued)

Structure	Source	Quantity	Abs/Cond.	Priority
100. Hammond and Clark Ditch	Dolores River	3.0 ft³/s	Absolute	12-18-33
101. Sellers and McClane Sup. D.	Lost Canyon	5.0 ft³/s	Absolute	12-31-33
102. Original Rico Flume	Silver Creek	.28 ft³/s 2.72 ft³/s	Absolute Conditional	3-08-37
103. Troy Rose Diversion	Dolores River	2.0 ft³/s	Absolute	3-08-37
104. Summit Reservoir	Lost Canyon	1,274 acre-ft	Absolute	12-01-38

Includes non-project rights senior to the main project rights.

Key: * Includes a water right located in District 61; all other rights are located in District 71

Table 13. Nonproject Water Rights Held by MVIC

Structure	Quantity	Basin Rank	Adj. Date	App. Date
Main Canal 1 and 2	707.7 ft³/s abs.	17	2-01-1892	11-25-1885
	87.3 ft³/s abs.	17(a)	2-01-1892	11-25-1885
	100 ft³/s abs.	101	3-22-63	11-25-1885
Narraguinnep Reservoir	5,969 acre-feet abs.	44	12-18-33	3-15-1888
	3,306 acre-feet abs.	74	12-18-33	10-28-07
	9,782 acre-feet abs.	86	12-18-33	8-17-22
	1,653 acre-feet abs.	131	3-22-63	5-01-56
Groundhog Reservoir	10,623 acre-feet abs.	69	12-18-33	8-01-05
	11,086 acre-feet abs.	90	12-18-33	10-24-29
Totten Lake	400 acre-feet abs.	72	12-18-33	4-25-07
	3,000 acre-feet abs.	129	3-22-63	2-01-51

feet will be used to irrigate 27,920 acres of full service land in the Dove Creek area. In addition, the project will annually supply 6,200 acre-feet of municipal and industrial water for the City of Cortez, 600 acre-feet for Dove Creek, and 900 acre-feet for rural domestic use. These project uses are all within the DWCD. In addition, the project will supply water for use by the Ute Mountain Ute Tribe. This includes 22,900 acre-feet to irrigate 7,500 acres of full service land in the Towaoc area and an additional 1,000 acre-feet for municipal and industrial use in this area. Annual deliveries from McPhee are summarized in Table 15.

In 1977, the DWCD and the MVIC entered into an agreement involving the transfer of certain water rights and the supply of water from the Dolores Project. MVIC's nonproject water rights were quantified in the following fashion: domestic uses will not exceed 3,000 acre-feet per year; irrigation uses will not exceed 150,400 acre-feet; the amount of diversion during the months of April, May, and June will be limited to no more than 72,000 acre-feet; however, MVIC retains the right to fill its present storage facilities (Narraguinnep, Groundhog, and Totten Reservoirs) during the months of April, May, and June with water beyond the 72,000 acre-foot

Table 14. Major Project Water Rights

Structure	Amount
McPhee Reservoir Inlet	585 ft^3/s
McPhee Reservoir	750,000 acre-feet
Cahone Reservoir Inlet	75 ft^3/s
Cahone Reservoir	13,800 acre-feet
Monument Creek Reservoir Inlet	40 ft^3/s
Monument Creek Reservoir	7,800 acre-feet
Ruin Canyon Reservoir Inlet	120 ft^3/s
Ruin Canyon Reservoir	30,000 acre-feet

Table 15. Annual Deliveries from McPhee Reservoir

Irrigation	**(average annual acre-feet)**
MVIC (supplemental)	13,700
Dove Creek (full service)	54,300
Ute Mountain (full service)	22,900
Total irrigation	90,900
Municipal and Industrial	
Cortez	6,200
Dove Creek	600
Rural domestic	900
Towaoc	1,000
Total M&I	8,700
Stream fishery (releases to Dolores)	25,400
Future fish and wildlife development (Utes)	1,600
Total annual average project water supply	126,600

limitation. MVIC agreed to transfer its water rights to the DWCD beyond those necessary to satisfy these nonproject rights. In return, the DWCD agreed to sell to MVIC sufficient project water necessary to irrigate 26,300 acres of MVIC land. This water supplements irrigation water already available under the original MVIC rights. The amount was estimated to be about 13,900 acre-feet per year with an expected range of 0 to 60,000 acre-feet "depending on the amount of water the Company is able to divert under its direct flow rights..."[4] In a 1989 agreement, MVIC transferred a number of conditional water rights to DWCD. These rights are listed in Table 16.[5] The 505 ft^3/s transferred to DWCD from the Main Canal right will take a priority lower than the 87.3 ft^3/s retained by the MVIC.

Table 17 summarizes water use in the Dolores River Basin above McPhee Reservoir. About 1,500 acres of land are irrigated in this area, primarily for hay. Average consumptive water use is about 2,338

Table 16. Water Rights Transferred by MVIC to DWCD

Structure	Amount	Basin Rank	Adj. Date	App. Date
Beaver Reservoir and Beaver Ditch	6,209.6 acre-feet conditional	90	12-18-33	10-24-29
Bear Creek Reservoir	7,261.49 acre-feet conditional	86	12-18-33	8-17-22
Dawson Reservoir	33,333.16 acre-feet conditional	86	12-18-33	8-17-22
Main Canal 1 and 2	505 ft3/s of the original 592.3 ft3/s conditional	17	2-01-1892	11-25-1885

Table 17. Water Use Upstream of McPhee Reservoir

	No. of Ditches	Irr. Acreage	Total Decreed Rights (Ft^3/s)	Historic Consumptive Use (Acre-Feet/yr) 1928-84
Dolores-Mainstem	7	534.4	30.13	953.8
East Fork - Dolores	18	835.1	68.00	1,176.4
West Fork - Dolores	5	157.0	21.85	208.6
Total	30	1,526.5	119.98	2,338.8
Source: Summary of Water Right Investigations for Dolores Water Conservancy District, Tipton and Kalmbach, Inc., May 27, 1987.				

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[4] Contract between the Dolores Water Conservancy District and the Montezuma Valley Irrigation Company for adjustment of water rights and sale of the use of irrigation water, Dolores Project, Colorado River Storage Project, September 23, 1977, page 5.

[5] Contract among the United States of America and the Dolores Water Conservancy District, the Montezuma Valley Irrigation Company, and the Ute Mountain Ute Tribe, January 6, 1989, Article 10 (a).

acre-feet per year. Of this consumptive use, perhaps 500 acre-feet is senior to the rights held by MVIC.[6]

According to the Definite Plan Report, flows in the Dolores River below McPhee Dam will average about 105,400 acre-feet a year. Releases are made from McPhee to help protect the downstream fishery. The Definite Plan Report specifies a minimum flow below McPhee of 78 second-feet during "wet" years, 50 second-feet during "normal" years, and 20 second-feet during "dry" years.[7] The Colorado Water Conservation Board (CWCB) holds an instream flow right between McPhee and the confluence with the San Miguel River for 78 ft^3/s. However, as discussed later in this section, the releases are not fully protected because they are not directly linked to the CWCB right.

Options for Obtaining Additional Streamflows

Flows of water in the Dolores River are determined primarily by the water diversion activities of MVIC and DWCD. Because of the magnitude of the water rights held by these two entities, they are logical sources for obtaining additional flows in the study area. In this section, some of the important considerations involved in analyzing the potential availability of this water will be discussed. The potential availability of water from two other recipients of Dolores Project water, the Ute Mountain Ute Indian Tribe and the City of Cortez, also will be considered. Reference will be made to modification of the operation of the project.

Montezuma Valley Irrigation Company (MVIC)

MVIC provides irrigation water to about 37,500 acres of land in the Montezuma Valley and also provides municipal and domestic water for Cortez, Towaoc, and some of the rural areas. The irrigable area to be supplied with Dolores Project water encompasses 26,300 acres. The irrigated croplands produce chiefly alfalfa, pasture, barley, oats, and corn silage for livestock feed. Apples are produced on some irrigated lands in the northeastern part of the area.[8] The lands are all either Class 2 or Class 3. Soils in the northern part of the Montezuma Valley are generally good while in the south they are less suitable for irrigation. Considerable portions of the area are underlain by mancos shale, a highly saline marine formation.

MVIC originally began as an irrigation district but was turned into a company in 1920. Its present articles of incorporation, established in 1980, include among its purposes "to distribute and supply water to the stockholders of this company, for domestic and irrigation purposes," and "to build, construct, purchase, operate, control, manage, and maintain ditches, canals, pipelines, and reservoirs, for the purpose of carrying, storing, and distributing water for irrigation and domestic purposes."[9] By a 1983 amendment, MVIC is empowered to sell surplus water under short-term contracts, with no expressed limitation on the form of use. There are no limitations in the bylaws or articles of incorporation on the transfer of the water rights held by MVIC.

The number of MVIC shareholders fluctuates, but recently that number has averaged about 1,075. There are 32,284 shares in the company, each share representing the right to 5.6 gallons per minute (0.0125 ft^3/s). Shortages are shared on a pro-rata basis.[10]

There are two general possibilities here to obtain additional supplies of water for the Dolores River. The first would be to acquire shares of MVIC water from current shareholders. The legal right held by a MVIC shareholder needs to be examined more closely, but, in general, it is possible under Colorado law to acquire such shares in a water company and change the place and purpose of use through a normal water court proceeding. Since these shares are for irrigation water, they would provide water to the river only during the historical period of use (i.e., the irrigation season). Presumably each share now provides a pro-rata right to the 150,400 acre-feet of irrigation water determined to be MVIC's legal entitlement from the Dolores River.

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[6] This information comes from an engineering report prepared in 1987 for the Dolores Water Conservancy District by Tipton and Kalmbach.

[7] The definition of wet and dry is based on the storage in McPhee at certain points in the year. A year will be considered "wet" if the end-of-April content of McPhee Reservoir exceeds 82 percent of the active capacity. A "dry" year exists if the March 1 prediction of the content of McPhee Reservoir at the end of June was less than or equal to 45 percent of the active capacity. Definite Plan Report, pages 68-69.

[8] Definite Plan Report, page 89.

[9] Certificates of Incorporation of the Montezuma Valley Irrigation Company, Art. 2 (1980); Bylaws of the Montezuma Valley Irrigation Company, Art. 2 (1980).

[10] MVIC Bylaws, Art. 14, §8.

A second possibility is to acquire a portion of MVIC's absolute water rights. There do not appear to be any direct legal barriers to such a purchase and transfer of a part of the MVIC water rights. However, the mechanics of such an arrangement need to be looked at more closely. Typically, entities are very reluctant to sell their underlying water rights since this would affect water availability for all shareholders.

A third option is to work out short-term contracts to lease "surplus" water from MVIC. Under this approach, MVIC maintains permanent ownership of the water rights. Under its bylaws it can sell water "surplus" to the needs of its shareholders in any given year. Because only year-to-year arrangements can be made, a disadvantage is the uncertainty of long-term availability of this water.

MVIC also will receive an annual average supply of 13,900 acre-feet from the Dolores Project. The 1977 contract between CWCD and MVIC states that "[MVIC] agrees not to sell the use of project water purchased under this contract to any person other than an irrigation water user for use on lands classified as irrigable by the Bureau of Reclamation within the boundaries of the project, either on a permanent or temporary basis."[11] This provision appears to limit the transferability of this water to other irrigation uses.

Some considerations potentially affecting the availability of MVIC water include the greatly increased reliability of supply to MVIC users as a consequence of the Dolores Project, the consequently likely greater use of water in the area, the salinity problems in the area, and the generally low-value agricultural economy in the area. These are all factors that should be analyzed in considering the feasibility of obtaining supplies of water from MVIC. Superficially, at least, these factors appear to suggest that water should be available in some form.

Dolores Water Conservancy District

The Dolores Water Conservancy District was established in the early 1960's. It serves as the repayment entity to the Bureau of Reclamation for the Dolores Project. Its boundaries are highly irregular, but in general they include the arable areas of Montezuma and Dolores Counties. The present and projected irrigation service areas within the DWCD include 27,860 full service acres in the Dove Creek area and 26,300 acres in the Montezuma Valley area that receive supplemental service. Irrigation water supplies from the Dolores Project are expected to average about 68,000 acre-feet annually with about 13,700 acre-feet going to the Montezuma Valley area and 54,300 acre-feet for the 27,860 acres of full service land in the Dove Creek area. There are about 140 farms in the Dove Creek area and about 769 in the Montezuma Valley area.

Agriculture in the Dove Creek area has been almost exclusively dry-land. Pinto beans and small grains, mostly wheat, have been grown in this area. With the availability of irrigation water it is expected that the crop types would shift to those supporting livestock production. The main field crops would be alfalfa, pasture, barley, oats, and corn silage for livestock feed. Beans and wheat would be produced under irrigation, but the total acreages devoted to these crops with irrigation would be considerably less than under dry-farm operations. Some fruit such as apples and peaches could be grown in the extreme southern portions of the Dove Creek area.

There are three types of charges for water supply service: a one-time "account" charge, a charge for repayment of a share of the capital costs of constructing the dam and related facilities, and a charge for operation, maintenance and replacement (OM&R). For full service lands these charges are presently $50 for the account, $1.35 per acre-foot for capital costs, and $15 per acre-foot for OM&R. For supplemental service (MVIC), there is a $10 account charge, $4.63 per acre-foot charge for capital costs, and $0.22 per acre-foot charge for OM&R.

McPhee Reservoir began filling in 1984 and in 1989 it reached full capacity. In 1987, water deliveries were made to the Fairview and Cahone areas. Deliveries were made to MVIC in 1988. Water will be delivered to the Pleasant View area in 1991 and to the Cross Canyon and Monument Creek portions of the Dove Creek area in 1992.

In connection with the repayment contract entered into by the DWCD and the United States in 1977, DWCD got commitments from farmers in the area to take project water in return for payments of a fixed charge to repay project facilities and an additional charge to cover operations, maintenance, and replacement costs. In August 1987, Robin Hollen, Jr. and a group of farmers filed suit against the DWCD seeking a determination that these commitments were obtained on the basis of misrepresentations and should be voided. The plaintiffs refer to themselves as the "Dryland Farmers." As of October 1989, this group included 32 people owning 9 farm units totaling 2,400 acres. About 2,100 of the 2,400 acres are in the Pleasant View block. Project water presently allocated to these farms totals 4,760 acre-feet.

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[11] DWCD-MVIC Contract, Art. 18.

The Dryland Farmers argue that they were told that the petitions they signed in 1977 were not binding, that the water would cost $9 per acre-foot (estimates now are about twice this much), that the obligations could be readily passed onto others if the farmers decided that they did not want the water, and generally that signing the petition was just to help others in the area who did want the water. As a consequence of this dispute, there is considerable uncertainty regarding the full extent of the land to be irrigated under the Dolores Project. If, in fact, these contracts are found not to be valid, then there will be up to 4,760 acre-feet of water unallocated within the project. One possibility is to seek some kind of Congressional action that would help to reallocate some of the costs of the project in return for permitting additional releases of water to the downstream area.

Ute Mountain Ute Tribe

The Ute Mountain Ute Tribe is to receive 22,900 acre-feet of water to irrigate 7,500 acres of full service land in the Towoac area. In addition, 1,000 acre-feet of municipal and industrial water is to be supplied to Towoac. An additional 800 acre-feet per year of water is available for fish and wildlife development on the reservation.

Dolores Project water is being provided to the tribe to satisfy the tribe's reserved water right entitlements. Under the Colorado Ute Indian Water Rights Final Settlement Agreement, established in 1986, the tribe agreed to take this water with the priority of the Dolores Project. Ordinarily, tribal reserved rights date from the establishment of the reservation which, in this case, was 1868. In 1988, Congress enacted the Colorado Ute Indian Water Rights Settlement Act.[12] The Settlement Act puts the Colorado Ute Indian Water Rights Final Settlement Agreement of December 10, 1986, into effect with some modifications.

The Settlement Act authorizes the Secretary of the Interior to supply the two Ute tribes with water from the Animas-La Plata and Dolores Projects in accordance with the terms of the settlement agreement. Tribal repayment obligations are as follows: repayment of construction costs allocable to the tribes' share of the project municipal and industrial (M&I) water is deferred until the water is used by the tribes or pursuant to a water use contract with them. After an increment of the tribes' M&I water is used, the tribes must begin to pay that increment's pro-rata share of the allocable construction costs, as well as the increment's pro-rata share of operation and maintenance costs.

The act also established a tribal development fund. For the Southern Utes, it authorizes a total of $17.5 million. The Mountain Utes are authorized to receive $32 million.

Finally, the act authorizes limited water marketing. It allows the tribe to "sell, exchange, lease, use, or otherwise dispose of any portion of a water right confirmed in the agreement and final consent decree off its reservation."[13] The legislation subjects such water used off the reservation to Colorado water law. It also provides that the tribe must pay allocated project construction costs for irrigation water leased for use off-reservation. Consequently, it appears that the project water allocated to the tribe could be purchased or leased. Additional research will be needed to determine if such water can be made available for downstream releases.

Currently there is no irrigation activity in the Towoac area. The plan for the original Towoac Canal has been altered to combine a section with the supply to the MVIC area. The Cortez-Towoac M&I Pipeline was deleted from the Dolores Project. The DWCD has agreed to construct this pipeline subject to financing from the State through the construction fund of the Colorado Water Conservation Board.

City of Cortez

The City of Cortez, which is the major commercial center and seat of Montezuma County, has an estimated population of 7,400. The municipal and domestic water supply for the city comes from the Dolores River. The city has some direct water rights. It also owns 120 shares of MVIC, each representing the right to 5.6 gallons per minute. The City of Cortez has contracted to receive about 6,000 acre-feet from the Dolores Project. It appears possible that the City of Cortez may not have use for this water. The Water Supply Act of July 3, 1958, allows a 50-year period for repayment of blocks of water used, commencing with the first use of the water. Presumably since Cortez has no immediate need for the water, it is able to defer payments for at least a 10-year period. The present plan calls for the city to take its water in two separate blocks (2,670 acre-feet in block 1 and 3,530 acre-feet in block 2).

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[12] Public Law 100-585, 102 Stat. 2973 (hereafter Settlement Act).

[13] Settlement Act, §5(c)(1).

Dolores Project Operation

Operation of the Dolores Project is based on maintaining certain water levels, partly to minimize the pumping costs from the reservoir. Presumably, if the extra pumping charges were paid, the reservoir could be maintained at a lower level, thereby allowing releases of additional water. Certainly there are other such operational options that should be considered. If this option is of interest, the legal limitations of making such changes and the approvals necessary can be looked into.

Legal Options for Protecting Streamflows

In 1973, the Colorado legislature established an instream flow program. It removed the statutory requirement that water must be diverted to obtain a legal right to its use. It added a section to the definition of "beneficial use" as follows: "For the benefit and enjoyment of present and future generations, "beneficial use" shall also include the appropriation by the State of Colorado in the manner prescribed by law of such minimum flows between specific points or levels for and on natural streams and lakes as are required to preserve the natural environment to a reasonable degree."[14] The Colorado Water Conservation Board was authorized to hold such instream flow rights, with the State Division of Wildlife and Division of Parks and Outdoor Recreation designated to recommend appropriate levels of flow to the CWCB.

In 1986, the law was amended to provide that the CWCB request "recommendations" from the United States Department of Agriculture and the United States Department of the Interior concerning instream flows.[15] This bill also explicitly allowed the CWCB to acquire water rights for instream flows by "grant, purchase, bequest, devise, lease, exchange, or other contractual agreement" with any person or governmental entity.[16] Finally, in 1987 the legislature enacted a provision affirming that the CWCB is the only person or entity authorized by State law to appropriate or acquire water for minimum stream flows.[17] This bill also provided that "any contract or agreement executed between the board and any person or governmental entity which provides water, water rights, or interests in water to the board shall be enforceable by either party...[in water court] according to the terms of the contract or agreement."[18] Thus, in Colorado, instream flows necessary to preserve the natural environment to a reasonable degree may either be appropriated by the CWCB or created by the transfer to the CWCB of an existing water right.

Water rights for recreational and fishery purposes also may be established under Colorado law. To obtain such a right, the water must be diverted, stored, or otherwise captured, possessed and controlled, and applied to a beneficial use.[19] The statutory definition of beneficial use includes the impoundment of water for recreational purposes, including fishery and wildlife.[20]

This type of nonconsumptive water right recently was approved by the Water Court for Division 4. The case involved an application by the Upper Gunnison River Conservancy District for a storage right, with the water being released into the stream to serve the recognized beneficial uses of fishery and recreation. The court concluded that by capturing the water, the conservancy district satisfied the diversion requirement. The court further concluded that by releasing the water into the stream to accomplish legitimate beneficial uses, the district obtained the protection of the State's constitutional assurance that the right to appropriate water shall never be denied. It further held that releases of such impounded water do not constitute an abandonment since it is being put to its intended beneficial use. Thus, the court recognized an instream flow right separate from the State program administered by the CWCB. This decision is on appeal to the Colorado Supreme Court.

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[14] Colo. Rev. Stat. §37-92-103(4)(1973).

[15] Colo. Rev. Stat. §37-92-102(3) (Supp. 1988).

[16] Colo. Rev. Stat. §37-92-102(3) (Supp. 1988).

[17] Colo. Rev. Stat. §37-92-102(3) (Supp. 1988).

[18] Colo. Rev. Stat. §37-92-102(3) (Supp. 1988).

[19] Colo. Rev. Stat. §37-92-305(9)(a) (Supp. 1988).

[20] Colo. Rev. Stat. §37-92-103(3)(1973).

The CWCB holds an instream flow right on the Dolores River between McPhee Reservoir and the confluence with the San Miguel River. The right was established in connection with the bypass flow releases established by the BOR for McPhee. Currently there are no additional available reliable flows in the Dolores River through the study area upon which an instream flow appropriation could be filed. If means can be found to obtain additional releases into the study area, protection for these flows should be established, if possible, through the CWCB. However, it may also be possible to establish a separate right to such flows under the theory followed in Division 4 Water Court.

The CWCB program now specifically authorizes agreements with other entities conveying existing water rights to the Board that are to be changed to instream flow purposes. If rights to existing uses are obtained, these rights could be transferred to the Board under such an agreement. One potential limitation on such an arrangement is the position of the CWCB that preservation of the natural environment to a reasonable degree can only be based on the flows of water necessary to protect a cold water fishery. If the water desired to be protected is for such a purpose, then there is likely to be little problem. If, on the other hand, additional flows are obtained for other purposes, such as recreation, then it appears that the CWCB would not accept such water rights. As William McDonald wrote in his letter of March 29, 1988, to Neil M. Morck, then BLM Colorado State Director, "The board will not appropriate instream flow water rights based on recreational boating flows. The Board reaches this conclusion because it believes that the relevant statutes do not authorize it to do so."

A second issue of concern is assuring adequate protection of minimum flows held by the CWCB. Apparently there is some question concerning whether currently committed releases from McPhee Dam are, in fact, being made. Monitoring gauges installed and maintained by the BLM may be necessary to keep accurate track of these releases. More troublesome is the apparent position of CWCB staff that these releases are available for diversion by downstream water users with rights senior to the instream flow decree held by the CWCB. The decree held by the CWCB protects flows below McPhee Dam to the confluence with the San Miguel River. However, apparently there is no agreement between the USDI, USBR, and CWCB tieing the releases from McPhee Dam to the instream flow right held by the CWCB. CWCB should assure that downstream users between these points only take water from the Dolores that would have been available at the time of his original appropriation. This could be accomplished by establishing an agreement between the USDI, USBR, and the CWCB dedicating these flows to the instream flow right.

ANALYSIS OF FLOW REQUIREMENTS

Recreation

The two most important flow-related recreation attributes are floatability and whitewater (Figures 30 and 31). Other attributes are also important, but the impact of flows on them is usually much less. Without certain floatability or whitewater conditions, most recreationists would not even take trips on the Dolores.[21] In determining flow needs for recreation on the Dolores, the most immediate focus should be on floatability and whitewater.

Floatability and Whitewater

Relationships between flows and both floatability and whitewater are best described by the

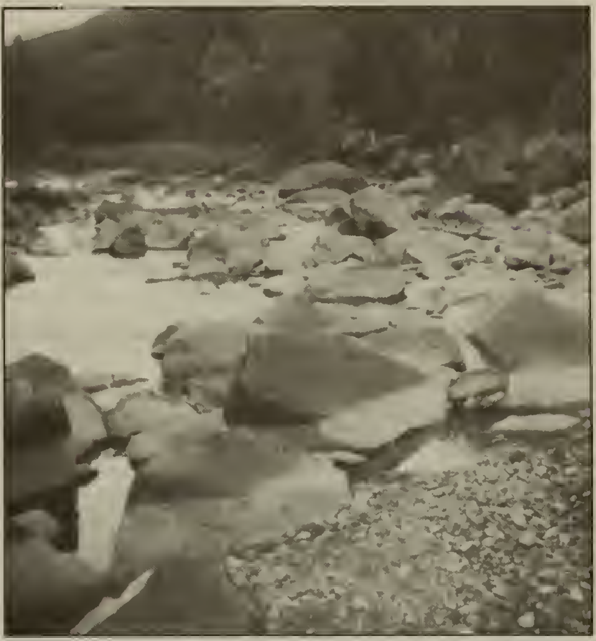

Figure 30. Floatability concerns at Snaggletooth Rapids during periods of low flow (approximately 20 ft^3/s).

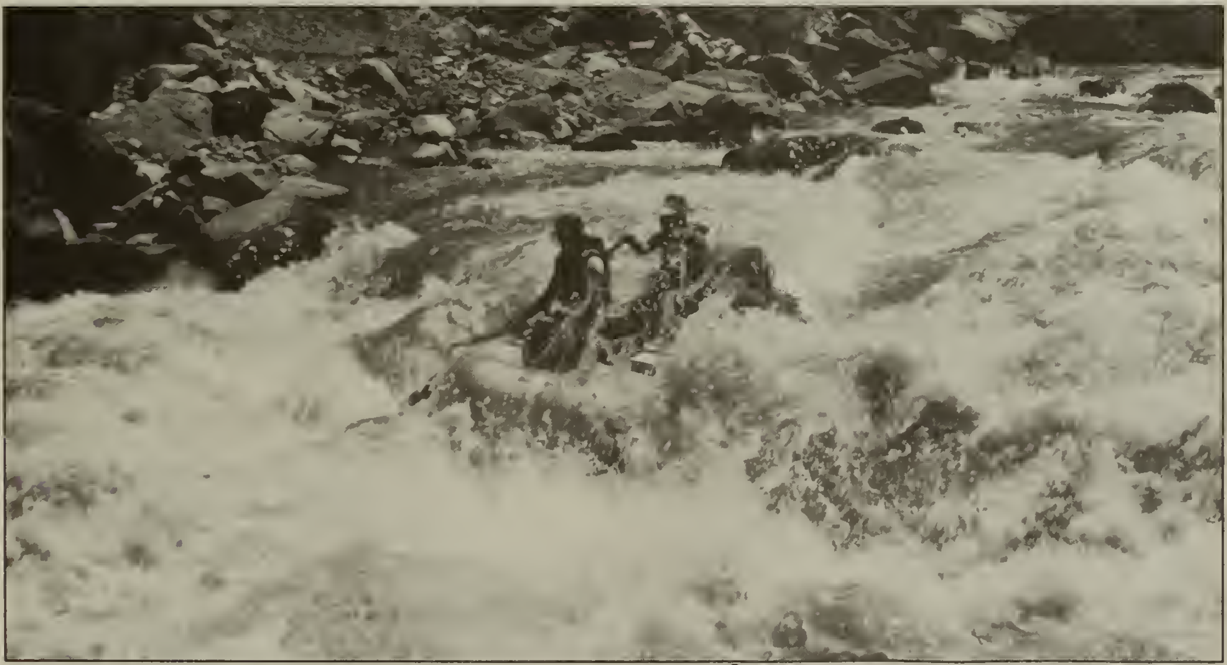

Figure 31. Whitewater rafting at an approximate flow at 2,000 ft^3/s in upper reach of Dolores River.

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[21] Over 56 percent of the experienced users surveyed reported that they require a certain flow level in order to take trips on the river, and another 36 percent said they prefer a certain flow level. In addition, over 71 percent of all users noted that flow levels influence the type of boat they use to float the river, while over 85 percent reported that flow levels influence how they take trips, such as whether they will run certain rapids, length and location of trip, etc.

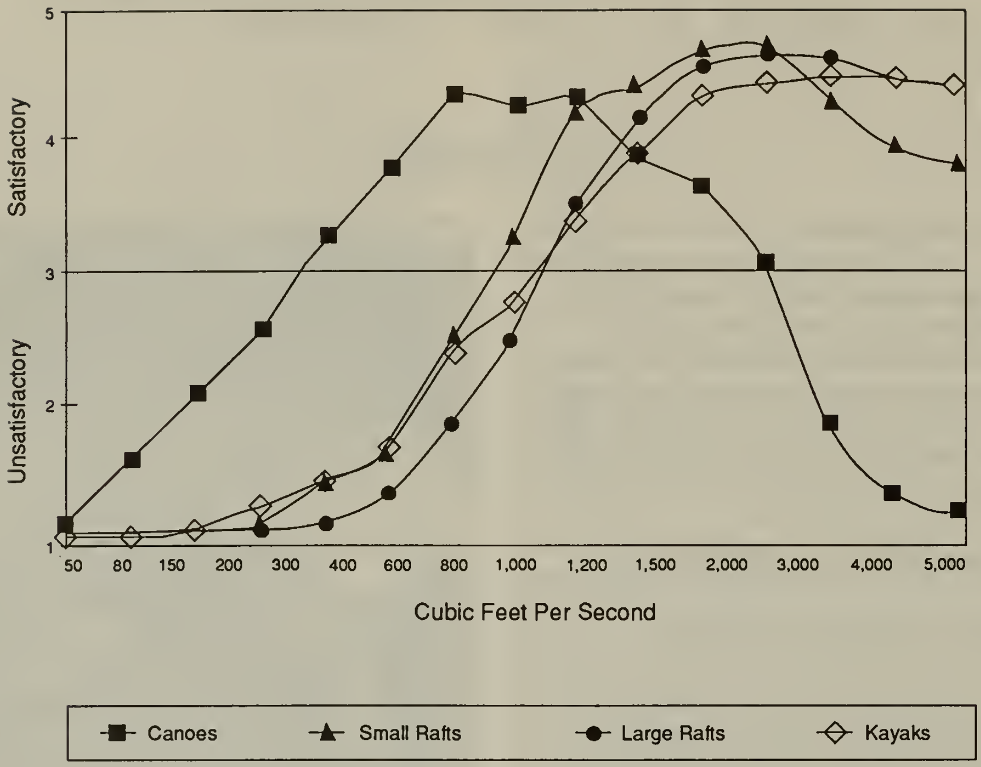

Figure 32. Flow evaluation curves for the upper canyon.

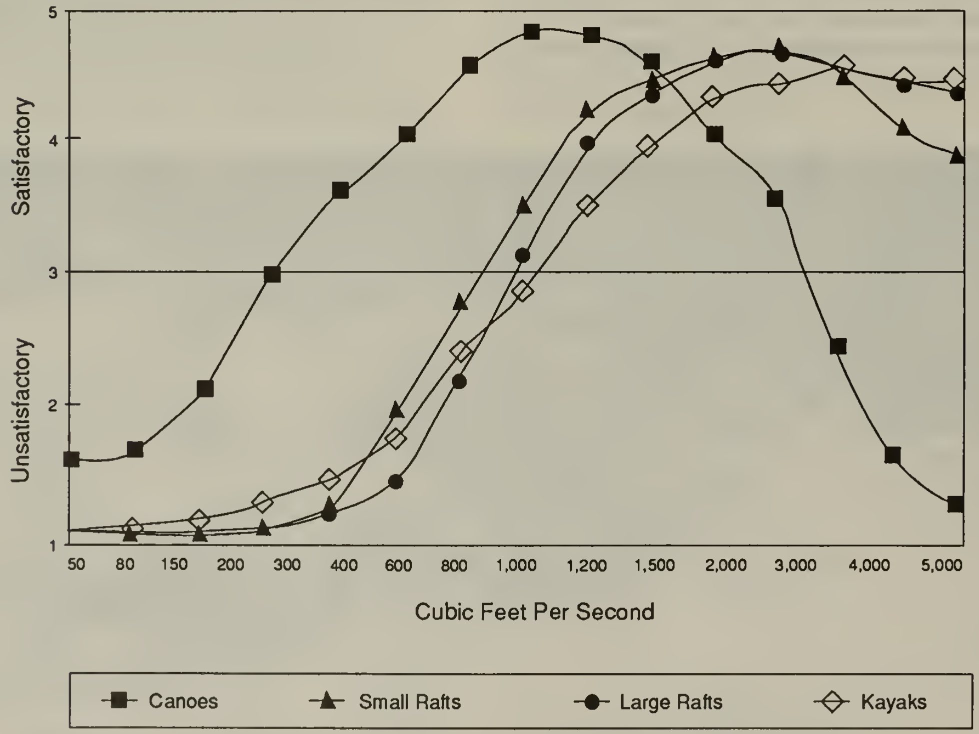

Figure 33. Flow evaluation curves for the lower canyon.

survey results for overall flow evaluations, which are presented in Figures 32 and 33.[22] Respondents were asked to rate various flow levels on a five point scale (from unsatisfactory to satisfactory) for a particular type of craft, and mean responses for each flow level are given on the graphs. The resultant curves provide information about minimum and optimum floatability and whitewater conditions.

Floatability refers to the flow conditions necessary to allow boaters to get down the river in various craft, that is, to use the river as a waterway for transportation. These conditions provide scenic rafting and canoeing opportunities (Figure 34). On the flow evaluation graphs, minimum floatability flows are shown by the point where the curve crosses the "neutral" line and mean ratings change from unsatisfactory to satisfactory.

Using this definition, minimum floatability conditions for various craft in both the upper and lower canyon present some obvious patterns. First, open canoes require less water (roughly 250 ft^3/s in the upper canyon and 200 ft^3/s in the lower) than either large rafts, small rafts, or kayaks (which range from 700-900 ft^3/s in the upper canyon and 600-800 ft^3/s in the lower).

Second, minimum floatability conditions in the upper canyon require about 20 percent larger flows than minimum floatability conditions in the lower canyon. Both of these findings fit with all anecdotal evidence and resource reconnaissance work on the river. Open canoes (and kayaks, for that matter)[23] can negotiate lower flow levels better than rafts, and portaging canoes past short unrunnable stretches is also much easier. With respect to the canyon

Figure 34. Canoeing on lower Dolores River rapids at approximately 250 ft^3/s.

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[22] Although users were also directly asked about minimum and optimum levels for floatability and whitewater attributes, the graphic display of the overall flow ratings provides a clear and simple way of discussing flow-attribute relationships and evaluations. The results from the individual questions provide support for the use and interpretation of the curves presented in Figures 12 and 13. Results for the individual questions are presented in Appendix A.

[23] The kayak "minimum floatability" results differ from those for other craft. Kayaks can obviously negotiate any flow level which is suitable for open canoes, but most kayakers prefer higher flows before they will take a trip. It appears that kayak ratings reflect preferences for whitewater even at low flow levels.

differences, the upper canyon features considerably more long stretches of "rock dodging," as well as larger rapids which become unrunnable at lower flows. In the lower canyon, floatability concerns are more often chutes which careen into walls or large boulder obstacles.

While floatable flows provide a minimum recreation opportunity, higher quality experiences result by adding the whitewater dimension. Good whitewater conditions require greater flows than floatability, and user concern for whitewater appears to figure into the flow evaluations as flows rise above minimum levels. On the graphs in Figures 32 and 33, whitewater conditions are "optimum" as curves reach their peak, the point where users report the highest ratings. These conditions provide optimum whitewater canoeing, rafting, and kayaking opportunities. Using this definition, ideal whitewater flows for open canoeists (roughly 800 ft^3/s in the upper canyon and 700 ft^3/s in the lower) are considerably less than for users in other craft (roughly 2,000 ft^3/s in the upper and lower canyons for rafts and 3,000 to 4,000 ft^3/s for kayakers). This is supported by anecdotal evidence and resource reconnaissance; average users in open canoes simply cannot negotiate the whitewater conditions runnable by average users in other craft.

These "optimum" flows are rarely available given current dam management, and the peaks for rafts and kayaks do not show much decline even at historically rare flows (those above 3,000 ft^3/s). These results suggest that whitewater conditions do not significantly decline for rafters and kayakers at higher flows. One might expect some decline, generally for safety reasons, at these higher flows, but it may be that the Dolores does not present safety hazards even at the highest historical flows. Results from the survey questions about minimum and optimum flows for safety, as well as the question on chief causes of boating accidents, offer further support for this notion. Only 20 percent of all users noted that "high water" was an important cause of accidents on the river, with much higher numbers reporting concern with inexperienced boaters or boater error (see Appendix A for these results).

The relatively "flat" shape of the rating curves has other implications as well, suggesting that there is a relatively wide range of flows which provide high quality whitewater, and it is possible to identify the flow which provides minimum whitewater conditions. This point can be described as the point on the upward swing of the curves when the marginal increase in the evaluations begins to decline. These conditions provide opportunities for minimum whitewater canoeing, rafting, and kayaking.

Using this definition, "minimum whitewater flows" are also lower for open canoes (roughly 600 ft^3/s in the upper canyon; 450 in the lower) than for other craft that are relatively similar (roughly 1,200 ft^3/s in the upper canyon; 1,000 ft^3/s in the lower). These numbers are comparable to the median responses to the question about minimum flows required "for a good ride through rapids" (see Appendix A for these results).

A summary of minimum and optimum flows for each type of craft is given in Table 18. The flows are based on the overall flow evaluations, as defined above, and are supported by individual survey questions. Flows have been rounded to the closest 50 ft^3/s.

Canoe Fishing Trips

The survey results from Table 18 reflect flow preferences for touring and whitewater experiences. Some users take canoe/fishing trips where the focus is not paddling. Canoe/fishing experiences are available in the upper reaches of the upper canyon (from Bradfield Bridge to Dove Creek). Anglers use canoes to travel on the river, although they apparently do not mind some portages or having to get out of their boats periodically to navigate the river (these users travel short distances each day). Although some users have apparently taken these types of trips at flows as low as 78 ft^3/s, resource reconnaissance and interviews suggest they involve extensive portaging and are more like "canoe-hiking." Based on resource reconnaissance, the trip is feasible at 125 ft^3/s, particularly if canoeists bring along camping gear. Analysis suggests the 125 ft^3/s figure be used to represent required flows for this opportunity.

Other Attributes

Relationships between flows and other attributes are less obvious than for floatability and whitewater, but nonetheless may be important. The following discussion briefly examines these relationships, presenting relevant information from the survey and resource reconnaissance on rate of travel, scenery/naturalness, camping, hiking, and fishing issues.

Experienced users were asked about their preferences for certain water levels relative to *rates of travel* (the flow below which users had to spend more time on the river and less time in camps or hiking

Table 18. Summary of Flow Evaluations

Type of Craft	Minimum Flow (floatability) ft^3/s	Minimum Flow (whitewater) ft^3/s	Optimum Flow (whitewater) ft^3/s
Upper Canyon:			
Open canoes	250	600	800
Small rafts	750	1,000	2,000
Large rafts	900	1,200	2,500
Kayaks	900	1,200	3,500
Lower Canyon:			
Open Canoes	200	600	900
Small rafts	600	1,000	2,000
Large rafts	750	1,000	2,000
Kayaks	800	1,200	3,000

than they would like). Results suggest that open canoeists felt flows below 300-400 ft^3/s were too slow, while rafters and kayakers felt that flows below 1,000-1,200 ft^3/s were too slow. This is further evidence that canoeists desire a different type of experience than users in other craft, and that considerably lower flows are acceptable to canoeists than would be acceptable to other users.

Relationships between flows and *scenery/ naturalness*, *camping*, and *hiking* values generally focus on the ability of flushing flows to create and maintain naturally occurring features of the physical environment (most notably open, flat, and sandy areas for camping, hiking, and fishing). "Using sandy beaches" was among the activities rated high by Dolores users (according to the 1988 survey), and most geomorphological data suggest that the size, frequency, and appearance of these areas depend upon periodic floods which carry and deposit large sediment loads, and clean existing bars of vegetation and traces of previous use. Flushing flows may also clear vegetation out of hiking trailheads, providing important access. This may have negative repercussions on some cultural resources (pictographs or petroglyphs), which become susceptible to visitor impacts.

Another possible link between flows and scenery/naturalness, fish, and wildlife values includes the ability of year-round flows to maintain natural vegetation patterns which provide quality fish and wildlife habitat. While separate sections of this report provide more detailed information on fish and wildlife flow needs, it should be noted that any loss in those resources could represent a significant loss in recreation value.

Preferences for Instream Flow Alternatives

The survey of experienced users also asked a series of questions about preferences for various flow scenarios and the tradeoffs implied by them. This information takes flow evaluations one step further, suggesting which instream flow alternatives might be acceptable to river users.

Overall Preferences for Flow Scenarios

The most obvious flow scenario choices are between high flow/shorter season options and lower flow/longer season options. Users were provided with five possible flow scenarios,[24] and were asked to rate them as "preferable," "acceptable," or "unacceptable." Results are presented in Table 19; figures are mean responses and allow easy comparisons among group preferences.[25] The table also ranks scenarios within user groups. A discussion of the five different scenarios is given below.

The *high flow/short season scenario* is more acceptable to kayakers and large raft floaters than to small raft floaters and canoeists, although mean rankings suggest that among kayakers this is the preferred scenario. Response frequencies further support this notion, as 50 percent of the kayakers rate this as preferable, compared to 38 percent for large rafts, 7 percent for canoes, and 17 percent for small rafts. This scenario was also rated unacceptable by 43 percent of the open canoeists and 50 percent of the small raft floaters. Canoeists consider this the most unacceptable scenario.

The *medium flows/medium-length season scenario* is the most acceptable of the five scenarios, ranking first among the rafters and canoeists and second among the kayakers. However, while a majority of rafters (53 percent for small rafts and 57 percent for large rafts) prefer this alternative, only 29 percent of the open canoeists rate this scenario preferable, with 71 percent reporting the acceptable response.

The *low flows/longer season scenario* is among the least acceptable scenarios for whitewater-oriented users (74 percent of the large raft floaters and 53 percent of the kayakers reported this scenario unacceptable), while it is unacceptable to significant minorities of small raft floaters and open canoeists as well (48 and 36 percent, respectively). However, a significant minority of open canoeists and small raft floaters consider this scenario preferable (43 and 24 percent, respectively).

Response to the range of flows/medium flow emphasis scenario was similar to response to the medium flow scenario; users generally consider it acceptable, although no majority felt it was preferable. Even among open canoeists, only 39 percent rated it preferable. It is interesting that slightly more than one-quarter of the rafters and kayakers consider this scenario unacceptable.

The *range of flows/low flow emphasis scenario* is the least acceptable scenario for the whitewater-oriented users (80 percent of the large raft floaters, 74

Table 19. Preferences for Flow Scenarios[1]

Scenario	Open canoes	Small rafts	Large rafts	Kayaks
High flows, short season	-0.4 (5)	-0.3 (3)	0.3 (2)	0.4 (1)
Medium flows, medium season	0.3 (1)	0.6 (1)	0.4 (1)	0.2 (2)
Low flows, longer season	0.1 (4)	-0.2 (4)	-0.7 (5)	-0.5 (4)
Range of flows, more medium flows	0.3 (1)	0.0 (2)	0.0 (3)	-0.2 (3)
Range of flows, more low flows	0.2 (3)	-0.6 (5)	-0.7 (4)	-0.6 (5)

[1] Numbers are mean scores. Positive scores indicate greater acceptance.
Scores above 0.33 indicate a "preferable" scenario.
Scores below -0.33 indicate an "unacceptable" scenario.
Number in ( ) is ranking for that group based on mean scores.

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[24] Flow scenarios were developed from hydrologists' estimates of available water in an average year and on current dam operation guidelines. The specific flows and time periods for each scenario are given in the text of the survey in Appendix A.

[25] Response frequencies for this question are given in Appendix A.

percent of the small raft floaters, and 63 percent of the kayakers reported this scenario as "unacceptable"), although it is generally acceptable among open canoeists (with about one-quarter reporting it as "acceptable" and almost one-half rating it as "preferable").

Taken together, these results show that few flow scenarios are generally acceptable to all groups, although both of the medium flow alternatives have greater acceptance levels than the others. It is interesting to note, however, that these medium flow alternatives are generally not considered "preferable" by any group. These scenarios may be tolerable compromises, but they are unlikely to generate much enthusiasm because of the lack of high quality whitewater associated with higher flows.

On the other hand, the high flow and low flow scenarios may serve one or more groups' interests, but also have the potential to be highly unacceptable to other groups. This is particularly true of the low flow scenarios, which essentially provide excellent canoeing flows at the expense of the whitewater-oriented users.

Tradeoff: Low Flow Versus High Flow Trips

Survey respondents were further asked about this potential tradeoff in a separate question on the survey. The question asked how users felt about a potential shift in experiences from the traditional high flow whitewater runs to lower flow, technical runs. Possible responses included "I will only take high or low water trips," "I prefer to take high or low water trips," or "I will take whatever trip the river offers."

Results show that a majority of rafters and kayakers will only take, or prefer to take high water trips (51 percent for kayaks and small rafts; 63 percent for large rafts). In contrast, only 7 percent of the open canoeists were in these two categories. Again, it is obvious that rafters and kayakers seek a different experience than canoeists, one that places greater emphasis on higher flows and whitewater.

On the other hand, while 27 percent of the canoeists said they preferred low water trips, not one said they would *only* take low water trips, and 67 percent reported that they would take whatever trip the river offered. These results suggest that canoeists are more adaptable to various flow levels and that their experience is less dependent on a narrow range of flows than other users. About 50 percent of the kayakers also chose the "whatever the river offers" category, suggesting that some of them may also be interested in future trips on the river even if the high flow whitewater was absent. Only 42 percent of users in small rafts and 31 percent of users in large rafts reported the same.

Holding Flows for Later Season Trips

Some users consider the early season high flows to be unusable because of the possibility of snowstorms or cold temperatures. One flow scenario which might address this "problem" is to hold flows behind the dam during the early spring and release them later in the year when weather conditions are better. The survey asked users about this alternative and found general support (roughly 70 percent for all boaters taken together). Kayakers were less supportive of this option (56 percent), presumably because their equipment allows them greater protection in poor weather.

When asked to give a date after which the boating season should begin, the overwhelming majority (92 percent) felt flows should be held until at least May 1st. Slightly more than half felt that flows should be held until May 15th, with only 15 percent reporting that the boating season should begin after June 1st. Canoeists generally felt that flows should be held until later in the season than other groups (80 percent said until May 15th, and 60 percent said until June 1st).

Increased Weekend Flows

Some users have suggested that the length of the boating season can be extended by offering higher flows on weekends, while conserving water during the week. The survey asked about this option, and results show that about 60 percent of all users are opposed, although a majority of kayakers (56 percent) felt this was a good idea. The most likely explanation for these results is that average trips are longer than the normal 2-day weekend, and it is not clear how 3- to 5-day trips would be affected by higher weekend flows. The group of kayakers in favor of the boosted flows may be willing to take shorter trips in return for the good whitewater flows.

A related question asked users how they felt about a potential tradeoff between boating flows (particularly boosted weekend flows) and their effect on native and trout fisheries. Results suggest that about one-third of the boaters felt that optimum boating flows were more important than optimum fishery conditions, while the balance felt that flows should protect either the native or trout fisheries (or both). It is interesting to note that fully 17 percent of the users in the survey added comments to this question, most of which suggested that managing for boating and fishery values was probably not an "all or nothing" issue, and that some compromise might be possible. Boating users on the Dolores obviously do not only want flows for whitewater or floatability reasons; they recognize that flows are also necessary to maintain other river values.

Willingness to Pay for Flows

Given the lack of high flows and brevity of boating seasons in recent years, some users have wondered if there might be ways of obtaining satisfactory boating flows through water rights purchases or other financial arrangements. In the survey, users were asked if they would be willing to pay for boatable flows *per person per day* if such arrangements were possible. Results show a great deal of support for this idea, with about 86 percent of all users saying they would be willing to pay some amount, and with over half (56 percent) saying they would pay between \$5 and \$10. Interestingly, few kayakers were willing to pay as much as other users (only 23 percent would pay more than \$5), possibly because they have substitute opportunities nearby (particularly the Animas).

Fish, Wildlife, and Riparian Habitat

Few terrestrial vertebrates are likely to be affected directly by flow levels. However, many of the species are dependent upon aquatic life or upon maintenance of riparian vegetation. Flows resulting in a drastic decrease in aquatic biomass and/or riparian vegetation could likely impact species such as river otters, peregrine falcons, etc. Selecting the proper flows to protect aquatic species should be more than adequate to protect identified terrestrial species.

Riparian vegetation along the Dolores River is composed mostly of willow, salt-cedar, or stands of boxelder. As with terrestrial vertebrates, no flow issues have been identified for riparian values, and flows recommended to protect the aquatic resource or provide channel maintenance should be more than adequate to protect riparian values. Actually, boxelders are considered a dryer site species, as well as an understory plant (Cooper, 1989). Unlike cottonwoods, they do not have flow requirements to propagate, but reproduce by sprouting after disturbance (such as removal by beaver) or by way of seeds. Seeds require good soil moisture where they are deposited to successfully germinate, but seedlings do not require continuous moisture for survival as do willow and cottonwood seedlings.

Flow regimes that result in drastically increased recreational use could cause some reduction in wildlife populations. Human disturbance from recreationists or others affects wildlife in many subtle ways, but methodology to assess cumulative impacts from such activity is virtually nonexistent. None of the wildlife species present in the area are likely to be significantly affected by increased recreational use on the order of 2-4 times the status quo.

The fisheries have been grouped into three seasons for the purpose of assessing flows.

They are as follows:

1. Brown trout spawning and egg incubation - September 1 to March 31.
2. Rainbow trout spawning and egg incubation - April 1 to June 30.
3. Adult and juvenile habitat - July 1 to August 31.

Selected flows for the above seasons are based upon the PHABSIM printout (Table 20) and are as follows:

1. Brown trout spawning and egg incubation - September 1 to March 31 - 65 ft^3/s.
2. Rainbow trout spawning and egg incubation - April 1 to June 30 - 125 ft^3/s.
3. Adult and juvenile habitat - July 1 to August 31 - 50 ft^3/s.

These flows are at the IFIM study site, and releases from McPhee Dam would need to be adjusted for channel losses (see Table 9).

The numbers underlined in Table 20 represent the optimal weighted usable area (based on the variables measured) for the respective life stages (e.g., brown trout spawning - 3365.78). If a flow was selected to optimize (100 percent) brown trout spawning, it would equal 150 ft^3/s. Likewise, a flow to optimize juvenile habitat for rainbow trout would equal 35 ft^3/s. However, no flow was selected that would be damaging to life stages that overlap the desired life stage (e.g., brown trout spawning), but an attempt was made to obtain an optimum for all life stages. At the same time that brown trout are spawning, there is a need to provide adult habitat for brown and rainbow trout, juvenile habitat for brown and rainbow trout, and some fry habitat for brown

Table 20. Weighted Usable Area for Life Stages at Various Flows (in ft^2/1,000 ft of stream)

RAINBOW TROUT				
Discharge	**Life Stages**			
ft^3/s	**Spawning**	**Fry**	**Juvenile**	**Adult**
15.00	12.72	**26688.76**	27261.36	32050.57
25.00	140.86	23173.80	28659.42	35545.69
27.70	191.04	22502.73	29011.28	36440.61
35.00	402.35	20432.13	**29340.59**	38313.78
50.00	840.45	17085.18	28963.77	41195.81
68.50	1125.11	13725.33	27551.07	43251.23
75.00	1209.30	12805.94	26928.04	**43751.32**
100.00	1593.96	10576.24	24606.75	42770.27
125.00	2042.44	9216.53	22167.15	41535.44
150.00	**2491.73**	8549.17	20307.39	40986.13
200.00	2291.37	8150.01	17408.76	39971.29
BROWN TROUT				
Discharge	**Life Stages**			
ft^3/s	**Spawning**	**Fry**	**Juvenile**	**Adult**
15.00	783.18	2962.15	14836.45	12031.11
25.00	1215.82	3793.88	17026.59	13995.07
27.70	1353.47	3997.62	17568.49	14513.50
35.00	1712.05	4370.15	18559.29	15541.47
50.00	2445.88	4907.97	**19297.99**	**16307.78**
68.50	2955.05	**5049.46**	19199.83	16271.92
75.00	3079.82	4981.40	19117.53	16136.23
100.00	3294.23	4267.91	18515.03	15490.61
125.00	3344.23	3774.87	17715.89	14592.29
150.00	**3365.78**	3329.87	16663.92	13841.42
200.00	3056.17	1885.18	14015.45	12558.61

Table 21. Percent of Weighted Usable Area Related to Flow (Sept. 1 - March 31)

BROWN TROUT		
Life stage	**150 ft^3/s**	**65 ft^3/s**
Spawning	100 %	88 %
Fry	66 %	99 %
Juvenile	86 %	99 %
Adult	84 %	99 %
RAINBOW TROUT		
Juvenile	69 %	94 %
Adult	96 %	99 %

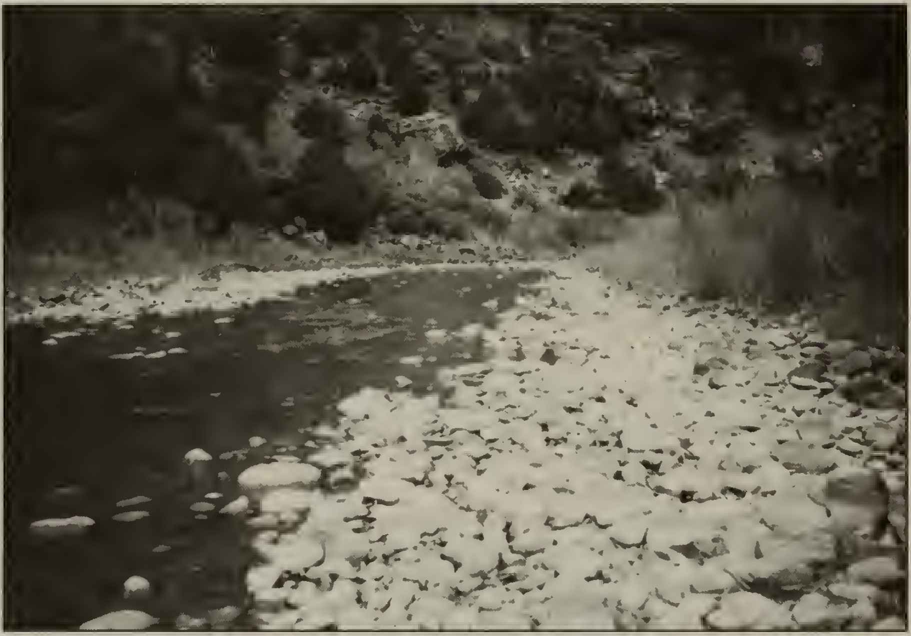

Figure 35. Low Dolores River flows (17 ft^3/s) depicting loss of potential aquatic habitat.

trout. Flows are evaluated for each life stage and balanced against overlapping life stages to provide a reasonable flow. From this analysis the fall/winter flow of 65 ft^3/s (Sept 1 - March 31) was derived. Table 21 helps define this process by displaying the percent of available habitat for two flows (150 ft^3/s versus 65 ft^3/s) for each life stage. This process was completed for each of the above defined seasons and life stages. Figure 35 shows the loss of aquatic habitat at low flows (approximately 17 ft^3/s).

As noted previously, the CDOW conducted an IFIM analysis on the Dolores River between McPhee Dam and Bradfield Bridge that produced a recommended year-round fisheries flow of 150 ft^3/s. The discrepancy between CDOW's flow and the BLM's flows as presented above results primarily from channel morphology differences. These differences can be described by a stream classification system developed by Rosgen, 1989. The river reach between McPhee Dam and Bradfield Bridge would be classified as a C_2 channel, characterized by cobble and very coarse gravel channel materials, a high width-to-depth ratio, and confinement by the valley walls. The river below Bradfield Bridge (BLM reach) is more characteristic of an F_3 channel, being more confined and having a lower width-to-depth ratio than the C_2 channel. These channel differences result in two distinct aquatic habitat types, with the F_3 channel requiring less streamflow to utilize the available fisheries habitat.

Earlier in this document the quality of rainbow trout habitat was bracketed as excellent, fair, and poor (Raleigh, 1989) based on the percent of average annual flow. The BLM and CDOW recommended flows place the Dolores River into the fair/poor category. However, Raleigh et al.'s (1984) model is a broad model that is intended to cover a wide range of systems. Raleigh's use of excellent, good, etc., to rate aquatic systems based on average annual flows, is meant to be an overall average. Significant variation to this rule can exist on the local level.

The IFIM methodology uses the PHABSIM model and habitat curves without regard for stream classification (excellent, good, etc.), and estimates flows that will provide optimal habitat for that particular site. The Dolores River's potential (excellent, good, etc.) likely will always be fair/poor when rated against other systems. It cannot compete with the Gulkana River in Alaska or the Madison River in Montana. That is not to say it is not worth managing. Desert stream systems (with their extreme climatic events) often do not have a moderate hydrograph that can sometimes lend stability and productivity to a particular aquatic system. Channel typing (Rosgen, 1989) provides a method for making allowances for local potential.

Concern has been expressed that the recommended flow of 50 ft^3/s may produce temperatures damaging to the aquatic resource during the months of July and August. Although the IFIM process has the capability to analyze flows related to temperature, a lack of data prevented such an analysis. Existing data (based on thermographs in 1984) indicate that flows in July and August have produced temperatures as high as 71 ^{o}F. Based on Raleigh et al. (1984), temperatures of 74 ^{o}F are required to retard growth and 77 ^{o}F is listed as the upper incipient lethal temperature for adult rainbow trout.

Flow recommendations have not been completed for the endemic species found in the Dolores River (e.g., bluehead sucker, etc.) due to lack of information and developed models to utilize the IFIM procedure. However, needs of endemic species should be met by flows recommended for brown and rainbow trout since they evolved in this system with a trout species (cutthroat trout) historically. The recommended flows would also apply to the reach of river from Disappointment Creek to Bedrock for those endemic species, since it is only water quality that limits trout from occurring below Disappointment Creek.

Stream Channel Form and Function

Rivers evolve according to their climatic and geologic framework, that is, they attempt to establish an equilibrium based upon flow and geomorphological conditions. The geomorphic functions of a river are dynamic, responding to normal conditions in a cyclical or incremental way. However, a river may respond radically to large changes in flow, sediment regime, or channel and floodplain conditions (Van Haveren et al., 1987). With the construction and filling of McPhee Reservoir, potential exists for radical changes in channel conditions resulting from large reductions in flow.

The determination of channel maintenance flows, that is, instream flows needed to maintain channel form and function, is not an exact science. Milhous (1986), in a review of several methods for determining channel maintenance flows, found that none of the methods reviewed were based on physical processes and concluded that none were satisfactory for determining a channel maintenance flow. For the Dolores River below McPhee Reservoir, the determination of a channel maintenance flow was based on qualitative analysis of expected changes in channel morphology, quantitative analysis of "at-station" hydraulic geometry, physical-process analysis of shear stress required for sediment transport, and statistical analysis of historical streamflow data.

Channel Morphology

Channel morphology and hydraulics change constantly with discharge and may change drastically with a long-term reduction in flow regime. Heede (1976) determined that channel responses requiring the shortest times and the lowest energy will occur first. He suggested that morphological features will adjust in a predictable order, that is, that bed form will change first, followed by bed material size, stream width, stream pattern, and longitudinal profile (slope). The direction of change may be estimated by the following general relationship (from Schumm, 1977):

$$Q \approx \frac{b, d, l}{S}$$

where Q = discharge
b = width
d = depth
l = meander wavelength
S = slope

Analyzing the case of a decrease in discharge alone, the following changes are predicted by the general relationship:

$$Q^- \approx b^-, d^-, l^-, S^+$$

where the +/- indicates the direction of change.

With the reduced streamflow resulting from operation of McPhee Reservoir, it is anticipated that the Dolores River between Bradfield Bridge and Disappointment Creek will decrease in width and depth and increase in slope. Meander wavelength likely will become shorter. The magnitude of the changes are best estimated by the hydraulic-geometry relations presented later in this section.

Below Disappointment Creek the effect of reduced Dolores River streamflows will be aggravated by the large sediment load entering the river from this major tributary (Figures 36 and 37). The effects of sediment load on channel morphology are predicted by Schumm (1977) with the following relation:

$$Q_S \approx \frac{b, l, S}{d, P}$$

where Q_S = sediment load
P = sinuosity

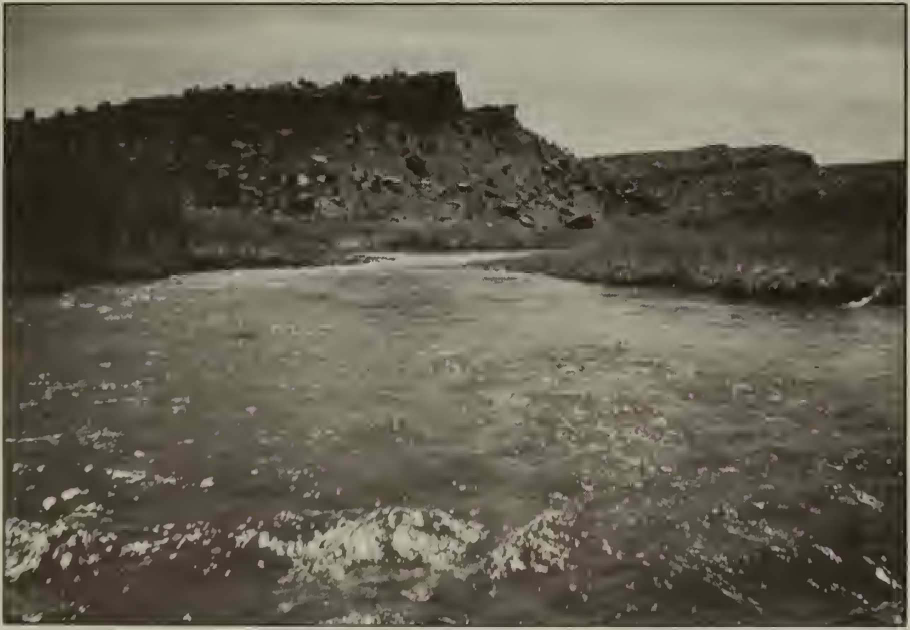

Figure 36. Dolores River upstream from Disappointment Creek confluence.

Using the two general relationships given above, the effect of decreased streamflow in an area of high sediment load may be expressed by the relation:

$$Q^- Q_S^+ \approx b^{\pm}, d^-, l^{\pm}, S^+, P^-, F^+$$

where F = width/depth ratio.

Using this relationship, the Dolores River below Disappointment Creek is expected to decrease in depth and sinuosity and increase in slope and width/depth ratio (Figure 38). The increase in width/depth ratio, regardless of change in width, means that even if width should decrease under the new flow regime, it likely would not do so as quickly as depth. Thus, the future channel of the Dolores River is likely to be shallower than the present channel. Table 22 lists the morphological features of the Dolores and the direction of expected change. The magnitude of expected changes in width and depth are demonstrated below in the discussion of channel hydraulic geometries.

Channel Hydraulic Geometry

Channels are maintained by a river's ability to establish and preserve the most efficient conditions for transporting water and sediment. The combination of flow and sediment vary from segment to segment within a river system. This is especially evident in the Dolores River when comparing reaches above and below Disappointment Creek. For the purpose of hydraulic analysis, the Dolores River was divided into two reaches on the basis of certain geomorphic characteristics, such as slope, sediment load, and channel form and roughness. The Dolores River above Disappointment Creek is characterized by steeper slopes (24 ft/mi) and a well-formed, stable, cobble/

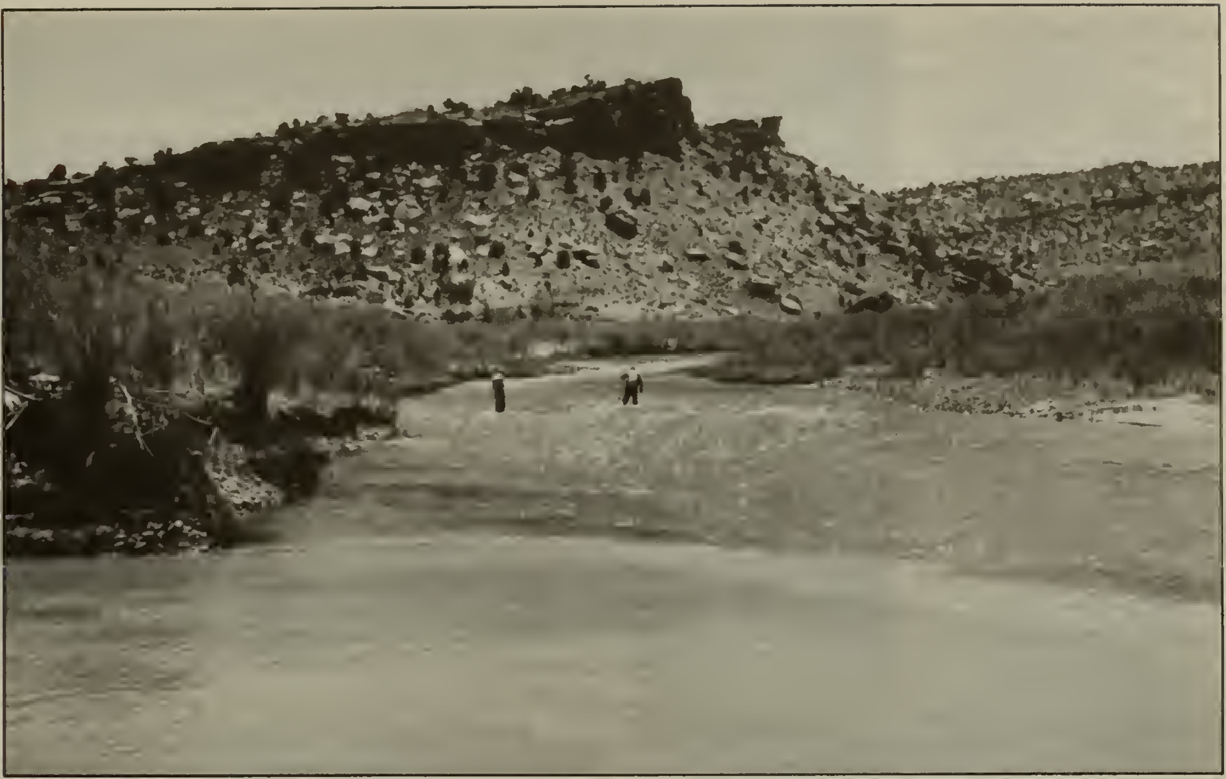

Figure 37. Confluence with Disappointment Creek depicting sediment loading.

Table 22. Estimated Adjustments in Channel Geometric and Morphological Features

Morphological Feature	Adjustment	
	Above Disappointment Creek	Below Disappointment Creek
width	decrease	decrease
depth	decrease	decrease
meander length	decrease	increase/decrease
gradient	increase	increase
pools	fill	fill
bed material size	decrease	decrease
bars	decrease	increase
riffles	increase	increase
width/depth ratio	increase slightly	increase

boulder channel, with roughness primarily associated with skin roughness. The Dolores River below Disappointment Creek has lower slopes (11 ft/mi) and a sandy alluvial channel, with roughness primarily associated with form roughness.

Three channel cross sections were selected as being representative of the general geomorphic conditions in the two reaches described above. The cross section near Bradfield Bridge (river mile 167) represents the Dolores River above Disappointment Creek, and the cross sections below Big Gyp Valley (river mile 103) and above La Sal Creek (river mile 73) represent the river below Disappointment Creek. Hydraulic variables for these cross sections are presented in Table 23.

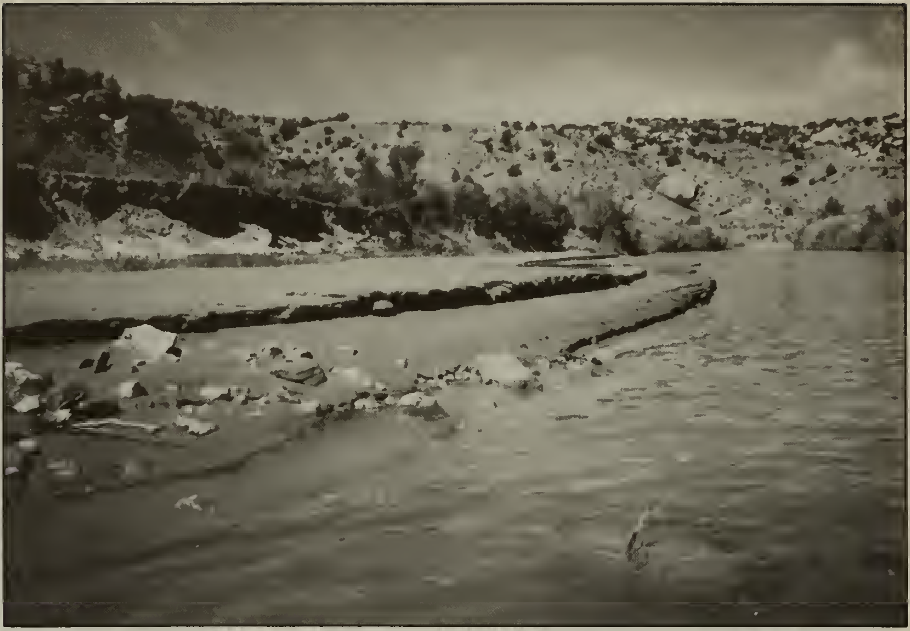

Figure 38. Dolores River downstream of Disappointment Creek confluence.

The exponents in the equations in Table 24 provide an estimate of the magnitude of change resulting from variations in flow. For example, in the earlier discussion of pre- and post-dam hydrology, it was shown that—prior to construction of McPhee Reservoir—the 1.5-year 7-day high flow was approximately 2,000 ft^3/s, while the post-dam 1.5-year 7-day high flow is expected to be on the order of about 1,000 ft^3/s. Assuming a 50 percent reduction in channel forming flows, the above equations yield estimates of changes in width, depth, and velocity at the representative cross sections in Table 25:

From this example, it is apparent that not all cross sections will respond to reductions in flow in the same way. Channel depth is most sensitive to changes in discharge at the cross sections near Bradfield Bridge and below Big Gyp Valley, while channel width is more sensitive at the cross section above La Sal Creek. Caution should be exercised in using these relationships to quantify effects of large changes in flow, particularly with respect to the velocity component, because it was developed using average water surface slope as described earlier and based upon existing channel geometry. Also, these equations only apply at the measured cross sections and assume no change in cross-section shape. However, some generalities can be made from these relations, that is, that reductions in high flows from the operation of McPhee Reservoir will result in a

Table 23. Channel Geometry for Three Representative Cross Sections at Bank-Full

Cross-section	Top Width (ft)	Depth (ft)	Velocity (ft^3/s)
Near Bradfield Bridge River Mile 167	110	3.4	6.04
Below Big Gyp Valley River Mile 103	128	3.8	5.3
Above La Sal Creek River Mile 73	92	4.9	6.0

Table 24. Hydraulic Geometric Relationships for Flows up to Bank-Full Discharge

Near Bradfield Bridge **River Mile 167**		
W =	47.35	$Q^{.1090}$
D =	.0539	$Q^{.5373}$
V =	.3856	$Q^{.3557}$
Below Big Gyp Valley **River Mile 103**		
W =	82.24	$Q^{.0560}$
D =	.0437	$Q^{.5686}$
V =	.3089	$Q^{.3619}$
Above La Sal Creek **River Mile 73**		
W =	1.160	$Q^{.5530}$
D =	.5863	$Q^{.2688}$
V =	1.472	$Q^{.1778}$

significantly narrower and shallower channel. Such changes in channel form could impact both fisheries and float boating on the river.

Sediment Transport

Stream channels react to changes in flow regime and sediment load. Changes in flow regime directly change stream power and the ability of the stream to transport sediment. Stream power is the available power per unit width of streambed and is proportional to the product of discharge and the gradient or slope of the water surface (Leopold and Dunne, 1978). It is this stream power that moves bed-material particles, thus forming the channel.

From the channel maintenance standpoint, the critical stream sections are below tributary drainages and where mid-channel bars occur (Figure 39). In order to maintain the existing channel, the river must be able to move the d_{50} or median particle size making up the streambed. For the analysis of sediment transport in the Dolores River, the area near the confluence with Disappointment Creek was considered critical for determination of channel maintenance flows. Surveyed cross sections and pebble count transects established in several pools and riffles directly above and below the confluence with Disappointment Creek provided estimates of the d_{50} and d_{84} for this critical sediment transport reach (Table 26).

The particle size information was used with the critical shear stress equations described earlier and rating tables developed for the surveyed cross sections to generate estimates of hydraulic radius and discharge needed to move particles of the indicated size. Table 27 displays the results for the data at Dolores River below Disappointment Creek.

Because only one set of hydraulic data was collected, it was necessary to estimate water surface slope for higher flows as described earlier in this report. Field measured slopes (.017) at the riffle were used for low flow shear-stress computations, and arithmetic averages of all pool and riffle slopes (.0068) were used for high flow shear-stress computations.

The flow required to move the d_{50} using the riffle slope of .017 is 60 ft^3/s and 97 ft^3/s for the Costa (1983) and Andrews (1983) methods, respectively. Using a more reasonable high-flow slope of .0068, the flow required to move the d_{50} is 1,600 ft^3/s and 2500 ft^3/s for the Costa and Andrews methods, respectively. Thus, it can be concluded that a flow in the range of 2,000 ft^3/s is required to move the d_{50}.

Table 25. Width, Depth, and Velocity Changes of Representative Locations

	Width	Depth	Velocity
Near Bradfield Bridge	-7%	-31%	-22%
Below Big Gyp Valley	-4%	-33%	-22%
Above La Sal Creek	-32%	-17%	-12%

Table 26. Pebble Count Data Dolores River Below Disappointment Creek

Station	d50 mm	d84 mm	Field Measured Slope
L1 (riffle)	74	181	.0133
L3 (riffle)	79	181	.005
L4 (pool)	21	84	.0007
R1 (riffle)	59	147	.02
R2 (pool)	36	97	.0008
R3 (riffle)	59	147	.0097
Dolores River above Disappointment Creek			
Station	**d_{50} mm**	**d_{84} mm**	**Field Measured Slope**
D1 (riffle)	111	208	.006
D3 (riffle)	137	208	.0138
D4 (pool)	16	128	.00075

Table 27. Dolores River Below Disappointment Creek Shear Stress Computations

d_{50} = 68mm d_{84} = 147mm		
Method	**Discharge Required to Move d_I**	**Slope**
Costa (d_{50})	60 ft^3/s 1,600 ft^3/s	.017 .0068
Andrews (d_{50})	97 ft^3/s 2,500 ft^3/s	.017 .0068
Costa (d_{84})	2,680 ft^3/s 8,685 ft^3/s	.017 .0068
Andrews (d_{84})	2,329 ft^3/s 5,594 ft^3/s	.017 .0068

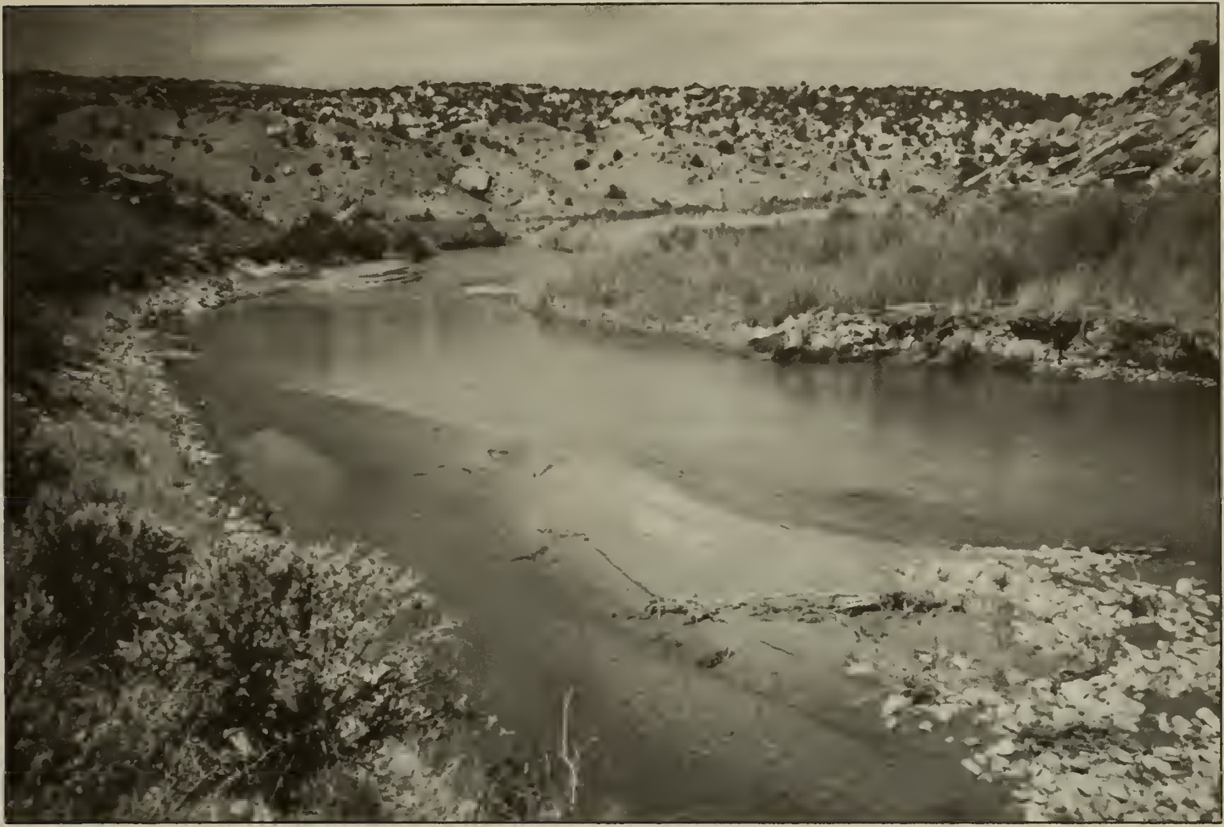

Figure 39. Sand bar establishment in lower reach of Dolores River.

Similarly, using the average slope as described above, the flow required to move the d_{84} is 8,685 ft^3/s and 5,594 ft^3/s for the Costa and Andrews methods, respectively. Thus a flow of approximately 7,000 ft^3/s may be required to move most of the bed materials. Such peak flows historically occurred at the 5-year recurrence interval at the Bedrock gauging station. The 7-day high flow of 6,641 ft^3/s for the Dolores River at Bedrock occurred at a 10-year recurrence interval. Thus, it can be assumed that—prior to construction of McPhee Reservoir—median size bed material moved on the average every 1 to 2 years, and even the larger bed material sizes moved about once every 5 to 10 years.

Pre-Dam and Post-Dam Streamflows

Earlier in this report, analysis of historical streamflow data yielded estimates of 1.5-year peak flows for the study reach ranging from about 2,500 ft^3/s for the Dolores River at Dolores to about 3,000 ft^3/s for the Dolores River at Bedrock. Seven-day high flows (1.5-year RI) were estimated at about 2,000 ft^3/s throughout the study reach, and bank-full flow estimates ranged from about 2,300 ft^3/s at Bradfield Bridge to about 2,800 ft^3/s at Bedrock. Analysis of releases from McPhee Reservoir produced an estimate of about 1,000 ft^3/s for the post-dam, 1.5-year, 7-day high flow.

Since the construction of McPhee Dam and Reservoir, the maintenance of extreme historic flow events is no longer probable. Based on the above analyses, the release of the historic pre-dam bank-full discharge, that is, 2,000 ft^3/s at Bradfield Bridge for 7 days, is estimated to be the flow which is most critical for maintaining channel stability and existing channel characteristics. The release of 2,000 ft^3/s for 7 days every other year, instead of the return period of 1.5 years, is recommended.

SUMMARY

The purpose of this chapter is to (1) summarize resource values and their corresponding flow requirements, and (2) develop a range of annual flow scenarios for management to consider. Out-of-stream uses allowed by McPhee Dam and other irrigation projects have dramatically changed the amount of water available in the Dolores system, and these changes have in turn had significant impacts on the resource values of the river. Recognizing this basic fact, the purpose of this study was to suggest ways to utilize currently or potentially available water quantities.

The chapter is organized into three parts. The first part lists the natural resource values on the Dolores River and summarizes, on the basis of the report, the required flows needed to protect or provide values. Following this, five flow scenarios are developed to reflect the range of flow strategies which should be considered for the river. Finally, a scenario discussion section is provided to help management gain insight about critical differences in flow scenarios, water availability, and resource tradeoffs.

Required Flows to Protect or Promote Critical Resource Values

Previous chapters of this report have identified critical resource values and have established relationships between these values and instream flows. A brief discussion of these critical values and the flows needed to provide them is presented below. Table 28 summarizes the values and required flows for the study area.

Table 28. Required Flows to Protect or Provide Resource Values

Value	Flow Requirement ft^3/s	
Canoe fishing experiences	125	
Scenic canoeing experiences	300	
Scenic rafting experiences	800	
Minimum whitewater rafting/kayaking experiences	1,100	
Optimum whitewater rafting/kayaking experiences	2,000	
Maintenance of channel form and function	2,000	for 7 days every other year
Sufficient depths and wetted perimeter for trout	125	during rainbow spawning/egg incubation (*4/1 to 6/30*)
	65	during brown spawning/egg incubation (*9/1 to 3/31*)
	50	Adult & Juvenile Habitat (*7/1 to 8/31*)

Providing Recreational Floating Opportunities

Information from survey results, interviews with veteran users, and resource reconnaissance suggests five basic types of recreation opportunities available on the Dolores River, each with specific flow needs. These five types of opportunities are described below.

1. Canoe fishing experiences: These experiences are available in the upper reaches of the upper canyon (from Bradfield Bridge to Dove Creek). Anglers use canoes to travel on the river, although they apparently do not mind some portages or having to get out of their boats periodically to navigate the river (these users travel short distances each day). Although some users have apparently taken these types of trips at flows as low as 78 ft^3/s, resource reconnaissance and interviews suggest they involve extensive portaging and are more like "canoe-hiking" than a paddling trip. Based on resource reconnaissance, the trip is feasible at 125 ft^3/s, particularly if canoeists bring along camping gear. Our analysis suggests the 125 ft^3/s figure be used to represent required flows for this opportunity.

2. Scenic canoeing experiences: These experiences are available in both canyons, and depend mostly on floatability conditions. While some dragging is acceptable to these users, they are not interested in the length and frequency of portages tolerated by float/fishing users. Information from both canyons indicates that 300 ft^3/s is required to create this opportunity. Although canoeists can get down the river at lower flows, those flows result in too many drags and portages for fully loaded canoes.

3. Scenic rafting (and optimum whitewater canoeing) experiences: These experiences are available in both canyons. Floatability is the issue with rafts, while whitewater conditions define the canoeing experiences. While some dragging is acceptable to the rafting users, it should be kept to a minimum. Results for both large and small rafts suggest that 800 ft^3/s should be used to represent the required instream flow for this opportunity.

4. Minimum whitewater rafting and kayaking experiences: These experiences are available in both canyons. Whitewater characteristics are the central concern, and floatability issues are less important. Results for small rafts, large rafts, and kayaks suggest that 1,100 ft^3/s should be used to represent the required instream flow for this opportunity. Less water is navigable, but lower flows lack the whitewater characteristics users require for this type of experience.

5. Optimum whitewater rafting and kayaking experiences: These experiences are available in both canyons. Whitewater is the critical issue, and this opportunity emphasizes high quality whitewater conditions. Results for small rafts, large rafts, and kayaks suggest that 2,000 ft^3/s is the required instream flow for this opportunity. Lower flows provide whitewater conditions, but users consistently rated lower flows as lower quality whitewater experiences.

Protecting Fishery Resource

Trout fishing has become an important recreational activity on the Dolores River. Protection of trout and native fisheries requires flows sufficient to provide certain depth, velocity, and wetted perimeters. Trout needs are believed to be greater than the needs of the native fisheries. If trout needs are met, the native fishery needs should be more than compensated. Spawning and egg incubation flows of 125 ft^3/s are needed for rainbow trout from April 1 until June 30. Spawning and egg incubation flows of 65 ft^3/s are needed for brown trout from September 1 until March 31. Flows of 50 ft^3/s are required for sufficient habitat for juvenile and adult rainbow and brown trout from July 1 until August 31. (These flows are at the IFIM study site, and releases from McPhee Dam would need to be adjusted for channel losses.) Other life stages that occur during the above periods (e.g., fry rainbow trout) are protected by those flows.

Maintaining Channel Form and Function

Channel form and function in the river will be altered by the operation of McPhee Dam and Reservoir. Channel sinuosity likely will decrease, thus increasing stream gradient. The lack of historical peak flows will result in a significantly narrower and shallower channel. Post-dam peak flows of about 1,000 ft^3/s may reduce stream width and depth as much as 30 percent. Such changes in channel form and size could impact both fisheries and float boating on the river. However, if historic bank-full flows (estimated to be about 2,000 ft^3/s for the 7-day high flow) can be maintained on average every other year, the channel should not change significantly from its present geomorphic characteristics.

In summary, the flow requirements listed above are necessary to protect or provide specified resource values. These flow requirements are the impetus of this instream flow assessment. Annual flow "scenarios" can be developed which represent different combinations of resource values, offering different blends of management objectives and providing opportunities to optimize multiple uses of the river.

Flow Scenarios

Choosing an appropriate flow scenario which optimizes resource values on the Dolores River is difficult. The obvious goal is to maintain natural values of the river and provide high quality recreation opportunities within the constraint of limited water availability (Figure 40). In many instances, this will require choosing between competing resource values.

This section of the report describes five alternative flow scenarios to help illustrate the critical choices which should be considered by management. These scenarios are based upon flow recommendations outlined in Table 28, and include annual flow requirements for a range of possible recreation opportunities. The scenarios, however, do not provide every possible scenario which could be chosen by managers. They are best used as *examples* of alternatives rather than alternatives themselves. A water management analysis could (1) identify more firm alternatives to meet annual flow needs for managers' chosen resource values; (2) analyze wet, normal, and dry year water availability options in conjunction with these more firm alternatives; and (3) suggest steps which should be taken by managers to acquire and protect those needed flow alternatives.

The remainder of the section discusses the assumptions, conditions, and tradeoffs that were considered in developing the five scenarios. The annual hydrographs for each of the scenarios are also provided (Figures 41-45), each shown with the hydrograph of the normal year post-dam water releases for comparative purposes. The post-dam streamflow volume of 105,400 acre-feet is the average annual flow based upon USBR operation plan for a 46-year period. The post-dam hydrographs were developed using the USBR data displayed in Table 6 of the Post-McPhee Dam Hydrology section.

In developing scenarios, the following assumptions and conditions were used:

1. Annual peak flows coincide with the Memorial Day weekend to ensure the opportunity for high quality recreation during the period which has traditionally had the highest use. This

Figure 40. Scenic boating opportunities include open-hull canoe floating.

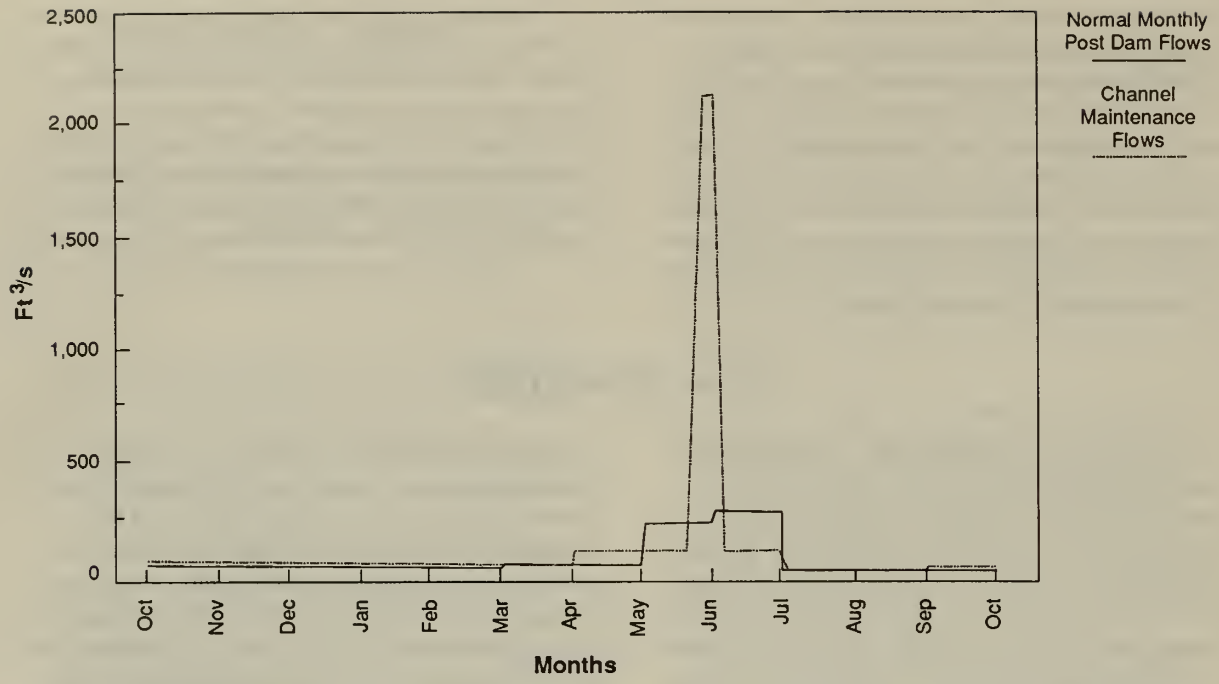

Figure 41. Annual hydrograph for scenario "A" channel maintenance/fishery, Dolores River, Colorado.

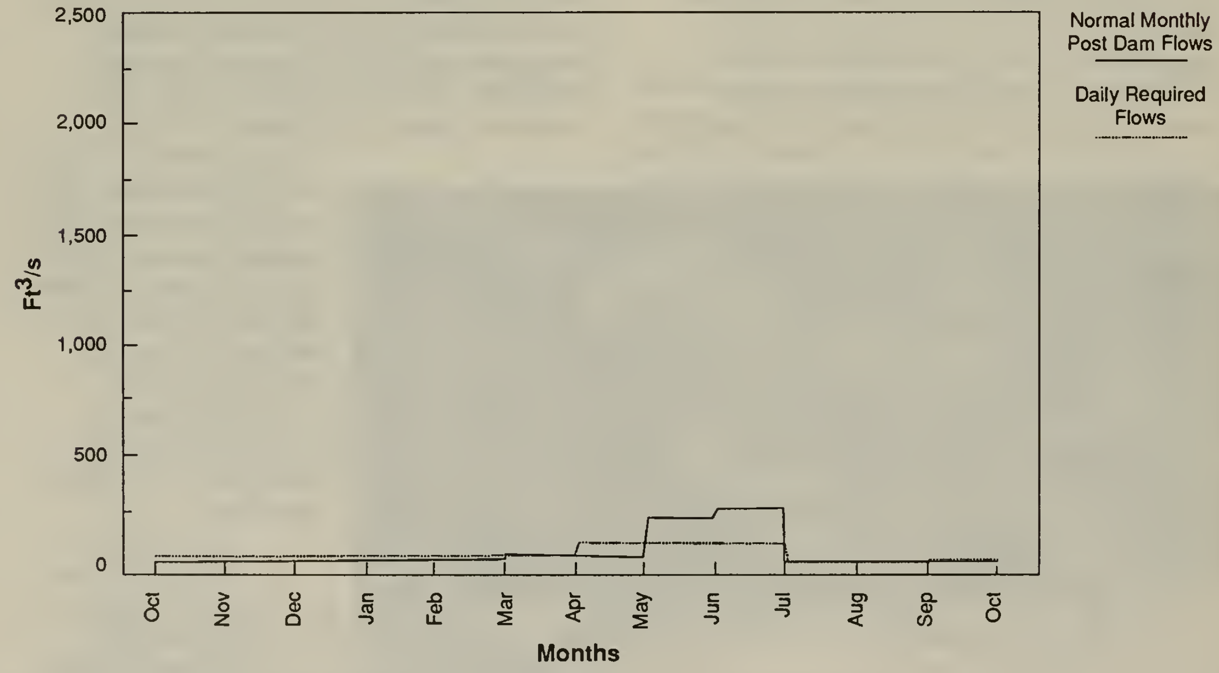

Figure 42. Annual hydrograph for scenario "B" fishery, Dolores River, Colorado.

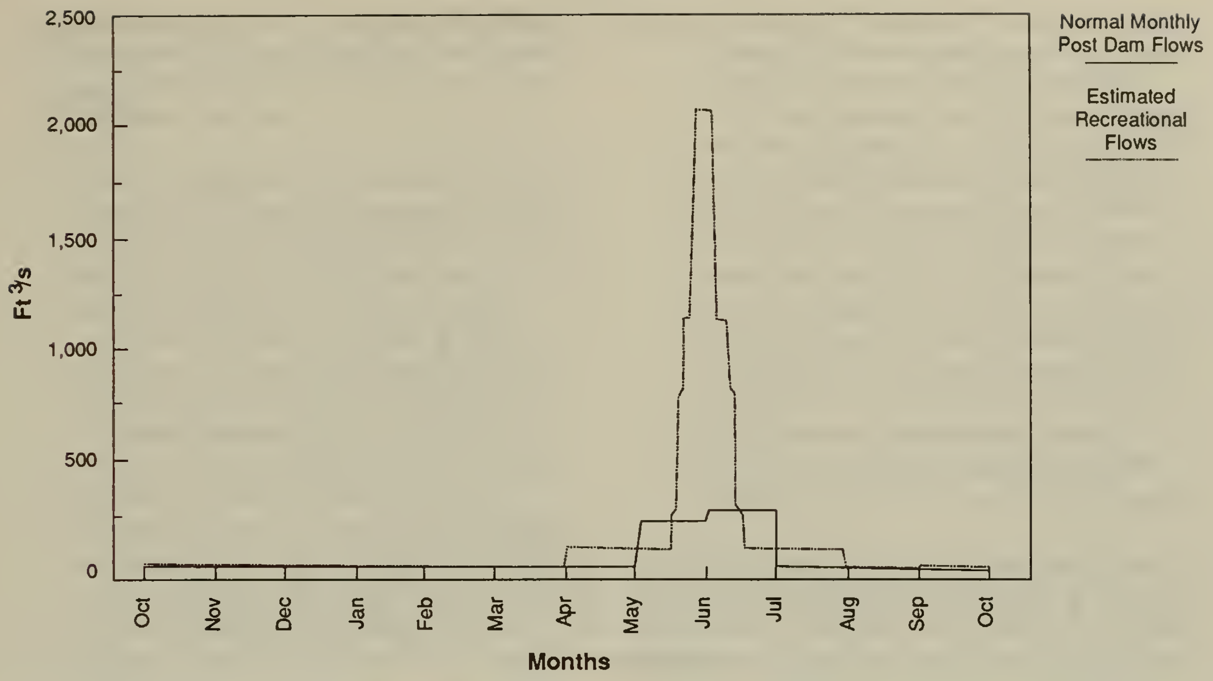

Figure 43. Annual hydrograph for scenario "C" whitewater recreation/ channel maintenance/fishery, Dolores River, Colorado.

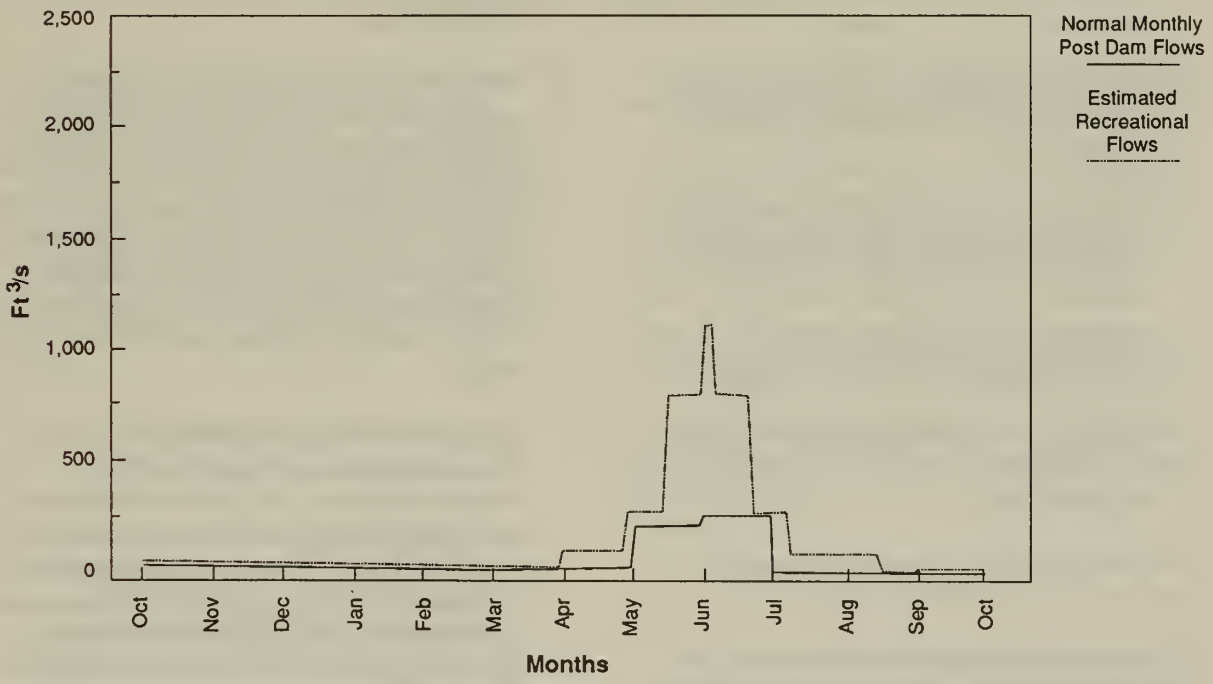

Figure 44. Annual hydrograph for scenario "D" scenic recreation/fishery, Dolores River, Colorado.

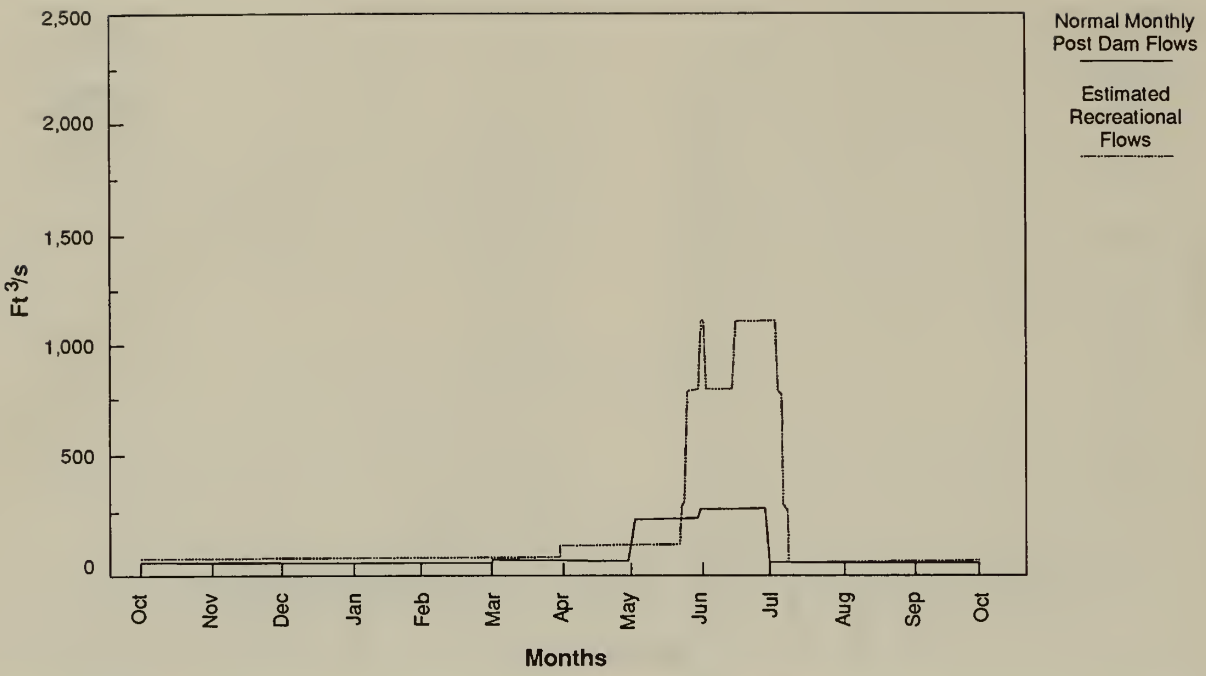

Figure 45. Annual hydrograph for scenario "E" combination recreation/fishery, Dolores River, Colorado.

weekend is normally within the natural snowmelt (high flow) season.

2. Incremental changes in flows do not exceed 500 ft^3/s per day because of dam operation guidelines.

3. When flow recommendations for more than one resource value overlap during any portion of the year, the highest flow was used.

4. Each scenario contains sufficient flows to protect riparian resources (i.e., vegetation).

5. Required flows for fish habitat are included in every scenario in order to sustain habitat on a long-term basis.

Five alternative flow scenarios are presented below.

1. Channel Maintenance/Fishery Scenario (see Figure 41). Channel maintenance flow would require 7 days of 2000 ft^3/s once every 2 years. Another 6 days will be required to meet the daily 500 ft^3/s incremental change allowed. Those amounts on the rising and falling limbs of the hydrograph are 1,500, 1,000, and 500 ft^3/s. During the rest of the year, flows are identical to the fishery flows described below.

2. Fishery Scenario (see Figure 42). Spawning and egg incubation flows of 125 ft^3/s (April 1 to June 30) are needed for rainbow trout and 65 ft^3/s (September 1 to March 31) for brown trout. Flows of 50 ft^3/s are required July 1 to August 31 for sufficient habitat for adult and juvenile brown and rainbow trout. Other life stages that occur during the above categories (e.g., fry rainbow) are protected by those flows.

3. Whitewater Recreation/Channel Maintenance/ Fishery Scenario (see Figure 43). This scenario emphasizes requirements for minimal and optimum whitewater boating experiences, while providing a diversity of other recreation opportunities. Flows to maintain fishery values are also provided throughout the year. This scenario allows 39 days for an array of floating experiences, with approximately 29 days of raftable flows. Twenty-four days provide flows with minimal or optimal whitewater characteristics. This scenario comes the closest to mimicking the pre-dam flows in terms of high flows although, because there is significantly less water available, the

duration of high flows is considerably shorter (see Table 29). Prior to the dam, flows greater than 1,200 ft^3/s were available on an average of 54.6 days per year.

4. Scenic Recreation/Fishery Scenario (see Figure 44). This scenario emphasizes requirements for scenic boating opportunities. A variety of other recreation opportunities is also provided, except for optimum whitewater opportunities. Flows to maintain fishery values are also provided throughout the year. This scenario allows 98 days for floating experiences in an average year, with approximately 36 days of raftable flows. Only 5 days provide flows with minimal whitewater characteristics, and no days provide optimum whitewater flows. This scenario represents the most significant shift from pre-dam conditions in terms of high flows, although it provides recreation seasons similar in length to pre-dam seasons.

5. Combination Recreation/Fishery Scenario (see Figure 45). This scenario emphasizes requirements for both scenic rafting and minimal whitewater opportunities. A diversity of other recreation opportunities is also provided, with the exception of optimum whitewater opportunities. Flows to maintain fishery values are also provided throughout the year. This scenario allows 53 days for floating experiences, with approximately 43 days of raftable flows. Five days of canoe-touring flows are also provided. No optimum whitewater flows are provided. This alternative also represents a significant shift from pre-dam flows in that high quality whitewater opportunities are neglected in favor of a longer raftable season.

Table 29 summarizes the scenarios with potential days of recreational floating and annual quantities of water needed. It should be noted that instream flow requirements of any flow scenario would necessitate lease or purchase of water right(s) or changes in reservoir operations.

Scenario Discussion

Associated with the preceding scenarios there are implicit resource tradeoffs and varying water availability considerations. The following discussion reflects some initial concerns which management might consider in analyzing scenarios as alternatives. Choosing appropriate flow alternatives necessarily involves value judgements about which resource values are more important, and may require some compromise between groups interested in different values.

Providing Recreational Floating Opportunities

The beauty, accessibility, and usability of the Dolores River in the study reach could be enhanced substantially by providing streamflows required for various floating experiences (i.e., canoe touring, whitewater rafting). It was previously noted that channel maintenance flows would also provide some recreational opportunities. Increases in spring releases during "normal" years would optimize certain floating opportunities. In years of above average runoff, spring bypass flows could be utilized to facilitate whitewater boating opportunities. This might require providing advance notice of large releases when possible. It might also mean scheduling releases to provide peak whitewater opportunities on weekends, especially the Memorial Day weekend.

Scenarios that emphasize whitewater rafting and kayaking require large volumes of water in relatively short periods. Optimum whitewater conditions with the short periods of high flow risk increased user (e.g., floater) demand and may lead to crowding. These scenarios may require more management of river users and planning for boating use on the river.

Scenario E extends the season for a variety of floating opportunities, although it does not provide optimal whitewater conditions. Expert users appear to favor this type of scenario more than the single-emphasis scenarios.

Protecting Fishery Resource

The Dolores River has been intensively used as a water source since the 1880's. In some years limited runoff, combined with out-of-basin water diversions, resulted in only intermittent streamflow in some stretches of the river during the summer months. Operation of McPhee Dam has changed the pattern and volume of streamflows in the Dolores River downstream through the study reach. Bypass flow releases have improved downstream fishery habitat conditions. As a minimum, these bypass flows guarantee availability of water that, in most years, should be able to sustain the fishery.

Presently, USBR makes its bypass releases according to its analysis of available flows in a given year. Once the determination is made that the year is wet, normal, or dry, the USBR makes fixed daily releases of 78, 50, or 20 ft^3/s accordingly. It is estimated that dry year releases of 20 ft^3/s will be inadequate to protect fisheries.

Providing flows to protect fishery resources means providing flows (albeit low flows) throughout the year. Cumulatively, these flows utilize a sizable amount of water relative to current availability, leaving little for other values such as recreational floating opportunities. For example, almost all of the water currently available would be required to provide both channel maintenance and fishery flows in the same year, minimizing flexibility to manage water for optimum recreational floating opportunities. Readers should note, however, that required flows for fish often overlap with required flows for recreation, and that providing fishery flows can be done in concert with providing flows for many recreation opportunities. While eliminating fishery flows would clearly free more water for recreation flows, all of the scenarios include fishery flows. For comparative purposes, Scenario B provides only the fishery flows.

Maintaining Channel Form and Function

The storage of spring runoff in McPhee has moderated peak flows in the study reach of the Dolores River. Through time, these changes will affect the geomorphological characteristics of the river, particularly channel attributes related to bankfull discharges. Maintaining these channel attributes will sustain or improve fish habitat and provide for recreation floating opportunities.

Given current water availability, providing flows necessary to maintain channel form and function means relatively high flows for relatively short periods. While these kinds of dam releases provide some streamflow required for both fishery and recreation values, they do not leave much water for recreational boating except during the high flow period. In order to illustrate how channel maintenance flows would affect these other values, two scenarios have been developed with the geomorphic flows, and three have been developed without them. Readers should note while examining these scenarios that channel maintenance flows are required only once every other year (on average).

Table 29. Annual Streamflow Volumes for Selected Flow Scenarios

Scenario	Total Recreation Season Length[1]	Rafting Season Length[2]	Whitewater Season Length[3]	Required Annual Volume (Acre-Feet)	Additional Requirements[4] (Acre-Feet)
A	91	13	11	96,700	None[5]
B	91	0	0	56,000	None[5]
C	91	26	21	131,110	26,110
D	101	37	5	127,310	22,310
E	100	43	21	130,510	25,510

[1] Number of days with flows above 125 ft^3/s.

[2] Number of days with flows above 800 ft^3/s.

[3] Number of days with flows above 1,100 ft^3/s.

[4] Water required over and above average post-dam flows of 105,000 acre-feet.

[5] Additional water would be required only if reservoir operations cannot meet seasonal flow requirements.

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APPENDIX A

Survey Results

Survey Cover

Everyone wants optimum water levels when floating the Dolores River. But this requires careful planning. There are a number of alternative flow regimes from the McPhee Dam, and the BLM in interested in establishing one which protects the fish, wildlife, and recreation values of the Dolores River. The purpose of this survey, which is one component of an instream flow needs study, is to find out how different flows affect river running on the Dolores.

As an experienced floater, you have detailed knowledge of the effects of different flows on river trips. Whether you have taken one trip or many, your opinions are important. By filling out this questionnaire, you may help the BLM obtain a satisfactory flow regime and protect valuable recreation experiences.

We're going to ask you about the effect of different water levels on whitewater and boatability, as well as your preferences for different flows and flow scenarios. Please answer the questions from your perspective as an experienced boater using the type of boat you indicate in question 1 on the next page.

Please try to answer all the questions, as a single missing response decreases the value of your other answers. Some of the questions may appear similar, but the concepts we are measuring are complex and need to be approached from different angles.

Sample Size

Surveys mailed out:	170
Undeliverables:	5
Returned uncompleted:	13
Returned completed:	128 (84 percent response rate)
Usable surveys (named boat type):	125

Questions and Results

1. There are at least five different types of boats used on the Dolores. Please indicate *one type of boat* that you have used on the river, and answer all questions with respect to that type of boat.

1 Large raft or dory (over 14 feet)	51 or 41 percent
2 Small raft or dory (14 feet or less)	43 or 34 percent
3 Open canoe or inflatable kayak	15 or 12 percent
4 Kayak	16 or 13 percent

2. How many trips have you taken on the Dolores River using this type of boat? (Write a number in each blank)

Trips in the upper canyon
(Bradfield Bridge to Slickrock)
Trips in the lower canyon
(Slickrock to Bedrock)

Upper Canyon:
6 percent had made only one trip
59 percent had made more than five trips
median number of trips: 8

Lower Canyon:
13 percent had made only one trip
47 percent had made more than five trips
median number of trips: 5

3. Are you an outfitter, a guide, or a private river runner? (Circle only one number)

1 Outfitter (owns outfitting business)
2 Guide (works for outfitter)
3 Private river runner
4 Other

35 percent were outfitters or guides (22 percent outfitters)
62 percent were private boaters
3 percent were "other"

4. Which segments of the Dolores do you usually run? (Circle only one number)

1 Upper river (Bradfield Bridge to Slickrock)
2 Lower river (Slickrock to Bedrock)
3 Upper and lower river
4 Other

45 percent run upper river only
10 percent run lower river only
38 percent run both
7 percent run other segments

The Dolores is only floatable for a short period each year. Please tell us how, if at all, flow levels affect your trip plans.

5. Where do you obtain flow or water level information (scheduled dam releases) before going on trips? (Circle all that apply)

A	BLM hotline	65 percent
B	Other hotline	31 percent
C	Outfitter	21 percent
D	Four Corners Marine in Durango	30 percent
E	Friends (word of mouth)	38 percent
F	Estimate based on weather	6 percent
G	Look at river	10 percent
H	I don't try to obtain flow information	6 percent

6. In general, how accurate and up-to-date is flow information?

1	Always accurate and up-to-date	8 percent
2	Usually accurate and up-to-date	80 percent
3	Rarely accurate or up-to-date	12 percent

7. Do flow levels influence if you will take a trip?

1 No
2 Yes, I prefer certain flow levels
3 Yes, I can only boat at certain flow levels

All Users:
8 percent said no
36 percent said yes, prefer certain flows
56 percent said yes, need certain flows

Upper Canyon Users Only:
2 percent said no
40 percent said yes, prefer certain flows
59 percent said yes, need certain flows

Lower Canyon Users Only:
8 percent said no
33 percent said yes, prefer certain flows
58 percent said yes, need certain flows

8. Do flow levels influence *the type of boat you take* on trips?

1 No
2 Yes

All Users:	71 percent said yes
Upper Canyon Users:	80 percent said yes
Lower Canyon Users:	67 percent said yes

9. Do flow levels influence *how you take* trips (when you plan to run particular rapids, where or when you plan to camp, how long you plan to spend on the river, etc.)?

1 No
2 Yes

All Users:	85 percent said yes
Upper Canyon Users:	86 percent said yes
Lower Canyon Users:	58 percent said yes

10. How far in advance do you usually plan trips?

_____ Days _____ Weeks _____ Months

All Users:

20	percent said days (1-7; median was 3)
42	percent said weeks (1-5; median was 2)
38	percent said months (1-12; median was 2)

Upper Canyon Users:

29	percent said days
36	percent said weeks
36	percent said months

Lower Canyon Users:

17	percent said days
34	percent said weeks
49	percent said months

Assuming a constant water level for an entire Dolores trip, please tell us about floatability on the river.

11. What is the *minimum water level* you need to float the Dolores?

_____ft^3/s in the upper canyon
_____ft^3/s in the lower canyon

See Tables A-1 and A-2.

12. What is the *optimum or best water level* for floating the Dolores?

_____ft^3/s in the upper canyon
_____ft^3/s in the lower canyon

See Tables A-1 and A-2.

13. At low water levels, users sometimes have to drag, line, or portage their boats over shallow areas or through rock-choked rapids. How often would you be willing to *drag, line, or portage your boat per day* before you felt the river was too low?

_____Times per day

See Tables A-1 and A-2.

14. Based on your experience as a Dolores boater, at what flow level is the water so low that you have to drag, line, or portage your boat more than the number of times you indicated above?

_____ft^3/s in the upper canyon
_____ft^3/s in the lower canyon

See Tables A-1 and A-2.

Table A-1. Floatability results in Upper Canyon.

Question	Open Canoes		Small Rafts		Large Rafts		Kayaks	
	Mean	Median	Mean	Median	Mean	Median	Mean	Median
Minimum flow needed (ft^3/s)	407	300	797	800	950	1,000	884	1,000
Optimum flow desired (ft^3/s)	869	800	1,860	1,500	2,853	2,500	2,981	2,500
Number of drags tolerated (median)	3		1		1		1	
Flow at which # of drags occurs (ft^3/s)	273	250	588	600	709	700	607	500
Percent tolerating less than 3 drags	73		86		93		100	

Table A-2. Floatability results in Lower Canyon.

Question	Open Canoes		Small Rafts		Large Rafts		Kayaks	
	Mean	Median	Mean	Median	Mean	Median	Mean	Median
Minimum flow needed (ft^3/s)	290	200	713	600	823	800	982	1,000
Optimum flow desired (ft^3/s)	869	800	1,818	1,500	2,597	2,000	2,913	2,500
Number of drags tolerated (median)	3		1		1		1	
Flow at which # of drags occurs (ft^3/s)	208	150	492	400	644	600	467	400

Different flow levels cause rapids to have different characteristics. Assuming you were to run an entire Dolores trip at a constant flow, please tell us your preferences for various flows with regard to whitewater.

15. What is the lowest water level you consider acceptable for a good ride through the rapids?

______ft^3/s in the upper canyon
______ft^3/s in the lower canyon

See Tables A-3 and A-4.

16. What water level provides *the best ride* through the rapids?

______ft^3/s in the upper canyon
______ft^3/s in the lower canyon

See Tables A-3 and A-4.

17. What water level provides *the safest ride* through the rapids (the level which is least likely to result in damaged equipment or injured people)?

______ft^3/s in the upper canyon
______ft^3/s in the lower canyon

See Tables A-3 and A-4.

18. Which of the following factors, in your opinion, are the most important causes of boating accidents on the Dolores?(Circle all that apply)

A	Equipment failure	7 percent
B	Very high water	20 percent
C	Very low water	33 percent
D	Boater inexperience	84 percent
E	Boater error	56 percent
F	Weather	5 percent
G	Other	7 percent

Write-in comments: alcohol, poor equipment

Table A-3. Whitewater results in Upper Canyon.

Question	Open Canoes		Small Rafts		Large Rafts		Kayaks	
	Mean	**Median**	**Mean**	**Median**	**Mean**	**Median**	**Mean**	**Median**
Minimum flow for whitewater(ft^3/s)	720	800	1,179	1,000	1,436	1,200	1,323	1,200
Optimum flow for whitewater (ft^3/s)	1,366	1,350	2,633	2,750	3,532	3,000	3,460	3,500
Safest flow (ft^3/s)	820	600	1,776	1,500	2,231	2,000	2,092	2,000

Table A-4. Whitewater results in Lower Canyon.

Question	Open Canoes		Small Rafts		Large Rafts		Kayaks	
	Mean	**Median**	**Mean**	**Median**	**Mean**	**Median**	**Mean**	**Median**
Minimum flow for whitewater (ft^3/s)	488	500	1,033	1,000	1,240	1,000	1,310	1,200
Optimum flow for whitewater (ft^3/s)	1,100	1,000	2,308	2,000	3,174	2,750	3,450	4,000
Safest flow (ft^3/s)	728	500	1,638	1,500	1,952	1,500	1,917	2,000

Table A-5. Rate of travel results.

Question	Open Canoes		Small Rafts		Large Rafts		Kayaks	
	Mean	**Median**	**Mean**	**Median**	**Mean**	**Median**	**Mean**	**Median**
Flow considered too slow (whole river) (ft^3/s)	388	300	1,053	1,000	1,092	1,000	1,229	1,000

Different whitewater characteristics are preferred by different people in different kinds of boats. Please tell us which characteristics of Dolores River rapids are the most important for providing good whitewater experiences.

	Most Important	**Important**	**Least Important**
Large holes	1	2	3
Large standing waves	1	2	3
Large boulders in the middle of big drops	1	2	3
Continuous rocks to dodge in long even gradient drops	1	2	3
Walls at the end of chutes	1	2	3

Characteristic	**Open canoes**	**Small rafts**	**Large rafts**	**Kayaks**
Big holes	2.4 (3)	2.1 (3)	1.9 (2)	1.8 (2)
Big waves	1.7 (2)	1.5 (1)	1.2 (1)	1.2 (1)
Boulders/drops	2.5 (4)	2.3 (4)	2.3 (4)	2.1 (4)
Rocks to dodge	1.6 (1)	1.9 (2)	2.0 (3)	1.8 (2)
Walls	2.6 (5)	2.8 (5)	2.5 (5)	2.9 (5)

1.0 - 1.6 = most important
1.7 - 2.3 = important
2.4 - 3.0 = least important

number in ( ) is ranking for each group based on mean scores

Different water levels result in different rates of travel on the river.

Please tell us about your preferences for certain water levels with regard to rates of travel.

19. Below_____ft^3/s, we have to spend more time on the river, and less time in camps or hiking side canyons than we would like in order to keep on schedule.

See Table A-5.

Releases from McPhee Dam provide a certain amount of water in the river each year. Current dam operation requires that most of this water be released during the spring runoff, usually without consideration of the effect on boating flows. If releases could e controlled to provide better boating experiences, how would you rate each of the following possible flow scenarios?

	Preferable	Acceptable	Unacceptable
High flows over a short season 1,500+ ft^3/s for 3 weeks	1	2	3
Moderately high flows over a medium-length season 1,000 ft^3/s for 5 weeks	1	2	3
Moderately low flows over a longer season 600 ft^3/s for 7 weeks	1	2	3
A range of flows with an extended moderate flow period 1,500 ft^3/s for 1 week 1,000 ft3/s for 1 week 600 ft^3/s for 3 weeks 300 ft^3/s for 1 week	1	2	3
A range of flows with an extended low flow period 1,500 ft^3/s for 1 week 1,000 ft^3/s for 1 week 600 ft^3/s for 3 weeks 300 ft^3/s for 5 weeks	1	2	3

	Open canoes			Small rafts			Large rafts			Kayaks		
	P	A	UA	P	A	UA	P	A	UA	P	A	UA
High flows, short season	07	50	43	17	33	50	38	52	10	50	44	06
Medium flows, medium season	29	71	00	57	43	00	53	37	10	44	31	25
Low flows, longer season	43	21	36	24	29	48	06	20	74	07	40	53
Range of flows, medium flows	39	54	08	29	48	24	28	42	30	06	69	25
Range of flows, more low flows	47	27	27	14	12	74	04	16	80	06	31	63

20. Some users favor having releases held during the week and boosted over the weekends (Friday through Monday). If this flow scenario were possible, would you favor it?

1 No
2 Yes

Percent who said yes:

All users:	40 percent
Canoes:	40 percent
Sm. Rafts:	29 percent
Lg. Rafts:	46 percent
Kayaks:	56 percent

21. Some users favor having releases held during the runoff period in spring so that water is available in early summer when weather is better. If this scenario were possible, would you favor it?

1 No —> skip to question 23
2 Yes

Percent saying yes:

All users:	69 percent
Canoes:	71 percent
Sm. rafts:	71 percent
Lg. rafts:	72 percent
Kayaks:	56 percent

22. After what date would you prefer the boating season to begin?

After _____/_____

Percent wanting flows after May 1:

All users:	92 percent
Canoes:	100 percent
Sm. rafts:	93 percent
Lg. rafts:	92 percent
Kayaks:	100 percent

Percent wanting flows after May 15:

All users:	53 percent
Canoes:	80 percent
Sm. rafts	43 percent
Lg. rafts:	49 percent
Kayaks:	31 percent

Percent wanting flows after June 1:

All users:	15 percent
Canoes:	60 percent
Sm. rafts:	28 percent
Lg. rafts:	3 percent
Kayaks:	6 percent

23. Certain flow scenarios (particularly those involving boosted weekend flows), may have detrimental effects on the developing trout fishery as well as on native fish species. How do you feel about this potential tradeoff? (Circle only one number)

1 Optimal conditions for trout are more important than optimum boating flows
2 Optimal conditions for native fish are more important than optimum boating flows
3 Optimal conditions for all fish species are more important than optimum boating flows
4 Optimum boating flows are more important than fish

For all users:

9 percent preferred managing for trout
27 percent preferred managing for natives
26 percent preferred managing for natives and trout
34 percent preferred managing for boating

Only 21 percent of the canoeists chose optimum boating conditions, while 40, 34, and 37 percent chose them for kayaks, large rafts, and small rafts, respectively.

24. Future flow regimes may shift the kind of boating experience available on the Dolores. Instead of high flow whitewater runs, the river may offer lower flow, technical runs for smaller rafts, open canoes, and kayaks. How do you feel about these competing experiences? (Circle only one number)

1 I will only take high flow whitewater trips
2 I prefer to take high flow whitewater trips
3 I prefer to take low flow trips
4 I will only take low flow trips
5 I will take whatever trip the river offers; the kind of trip is not as important as being on the river.

For all users:

6 percent said they would only take high water trips
0 percent said they would only take low water trips
45 percent said they preferred high water trips
8 percent said they preferred low water trips
41 percent said they will take what the river offers

Prefer/will only take high water trips:

7 percent of canoeists (7 prefer)
51 percent of sm. rafters (44 prefer)
63 percent of lg. rafters (57 prefer)
51 percent of kayakers (38 prefer)

Prefer low water trips:

27 percent of canoeists
7 percent of small rafters
6 percent of large rafts
0 percent of kayaks

Take what the river offers:

67 percent of canoeists
42 percent of sm. rafters
31 percent of lg. rafters
50 percent for kayakers

25. Ensuring satisfactory boating flows could involve purchasing water rights or other financial arrangements with dam operators and water users. If purchases or other arrangements become feasible, how much would you be willing to pay for boatable flows *per person per day* on the river?

$_____per person per day

Percent willing to pay $3 or more:

All users:	61 percent
Canoes:	67 percent
Sm. rafts:	67 percent
Lg. rafts:	63 percent
Kayaks:	37 percent

We would like you to give an overall evaluation for each of the following water levels for the upper canyon. *Make this evaluation based upon your experience as a trip leader using the boat you indicated in Question 1. Assume the water level is constant for the whole trip. (Circle only one number)*

ft^3/s	**Unsatisfactory**		**Neutral**		**Satisfactory**
50	1	2	3	4	5
80	1	2	3	4	5
150	1	2	3	4	5
200	1	2	3	4	5
300	1	2	3	4	5
400	1	2	3	4	5
600	1	2	3	4	5
800	1	2	3	4	5
1,000	1	2	3	4	5
1,200	1	2	3	4	5
1,500	1	2	3	4	5
2,000	1	2	3	4	5
3,000	1	2	3	4	5
4,000	1	2	3	4	5
5,000	1	2	3	4	5

See graph in recreation section for results.

Finally, please evaluate each of the following water levels for the lower canyon. *Again, make this evaluation based upon your experience as a trip leader using the boat you indicated in Question 1. (Circle one number)*

Same response format as above.
See graph in recreation section for results.

APPENDIX B

Field Notes

Day 1 - May 15th

Transect #1 - Bull Canyon

The river expressed a moderate to steep gradient that had a good pool/riffle ratio (50/50). The streambanks were totally stable with willows being the dominant woody species of vegetation. The system is well confined and entrenched (with a high sinuosity) but still expressed a fair amount of meandering within its confinement (a channel within a channel). Lack of woody debris in the willows indicates that little to no overbank flooding is taking place in this section of the river. Substrate seemed to be dominated by cobble and appeared relatively clean (good interstitial space). Class three rapids for canoes exist at this site.

The remainder of day 1 the river stayed much the same as described at transect #1. Several deep pools >5 feet were present in this section of the river at a flow of 600 ft^3/s. Recent rainfall, altering the clarity of the river, prevented us from observing the substrate as we floated this section, but where we did check it, it was similar to what was found at transect #1.

Day 2 - May 16th

The river started to change some after leaving campsite #1 (Anderson Mesa Area). It started to exhibit long runs and/or glides with shorter riffle areas dumping into large pools versus the pool/riffle expression noted on day 1. Kick samples for macroinvertebrates, in riffle areas, found few species or numbers. Confinement and entrenchment were much the same as day 1. Riparian vegetation was again dominated by willow until we reached a point about halfway between Spring Canyon and Coyote Wash, where it changed to salt cedar. Substrate stayed the same as found on day 1 (cobble). Afternoon rain showers, accumulating off canyon walls, were observed providing irrigation to sites with riparian vegetation. This demonstrated the means of maintenance of woody vegetation along the river, in this section, since it appeared that not a lot of overbank flooding is taking place. Streambanks observed on day two were totally stable. This section of the river had fewer sites for production of riparian vegetation as a result of confinement than observed on day one.

Transect #2 - Spring Canyon

Due to large amounts of discharge out of Spring Canyon, the Dolores River is confined to river left during low flows creating rapids that are a floating issue. At the site of transect #2 the river is a straight channel for approximately one-half mile. Substrate at the site is a mix of cobble and large boulders. The reach would be considered stable. The site is confined by canyon walls and has very little potential for production of riparian vegetation. Existing riparian vegetation is dominated by willows.

Day 3 - May 17th

Transect #3 - La Sal Rapids

The canyon began to broaden out in this area with evidence of past degradation or downcutting (more terraces/benches). For the most part, the system would be classified as stable but did start to show some bank erosion. The stream bottom substrate still was dominated by cobble, but more fines were beginning to make their presence in runs and glides. At the site of the rapids large boulders are present. Streambank vegetation was a mix of salt cedar and willows, with the willows showing heavy impacts from livestock grazing. On the upper terraces the woody riparian species are being or have been replaced by sagebrush. The remainder of the river to Bedrock was pretty much the same.

On day 3 more evidence of beaver activity was observed, but beaver are present in the entire river system. With the decrease in flows (600 to 125 ft^3/s), the presence of fish became more evident. Numerous times, as we approached point bars, schools of bluehead and flannelmouth suckers were observed. At the junction of La Sal Creek and the Dolores River, Tom Beck (CDOW) observed several bluehead suckers moving into the feeder stream, possibly to spawn.

Day 4 - May 18th

Transect #4 - Confluence of Dolores River and Disappointment Creek

At the confluence of the Dolores River and Disappointment Creek, the water quality is greatly altered by the discharge out of Disappointment Creek. Riparian vegetation on the river was dominated by willow with some cottonwoods, while on Disappointment Creek it was dominated by salt cedar. The river would be considered stable with less confinement and entrenchment as observed downstream the previous 3 days. Above Disappointment Creek the river expressed an excellent pool/riffle ratio and good trout habitat. The macroinvertebrate population (kick samples) were numerous and included a wide variety of species. Downstream, water quality would be the limiting factor for trout. Like La Sal Creek, we observed a fair number of bluehead suckers moving into Disappointment Creek, possibly to spawn. As I walked up Disappointment Creek, suckers were present for approximately 1 mile.

Day 5 - May 19th

Transect #5 and #6 - Dove Creek Pump Station - Snaggletooth Rock

Both of these transects were boating issues. The habitat was basically the same for both reaches. The pool/riffle ratio was somewhere between 50/50 to 60/40 and provided high quality pools that were > 5 feet deep. Stream bottom substrate was clean and composed mostly of gravel and cobble, with some large boulders. Kick samples show a good and diverse macroinvertebrate population. The system would be considered well confined and entrenched. Streambanks were stable and the vegetation along th river was a mix of willows and ponderosa. Overall, this reach appeared to provide good habitat for trout.

A fisherman had caught two rainbow trout that morning around transect #6. One was 39 cm in total length and weighed .8 kg; the other was 47 cm long and weighed 1.4 kg. Numerous fish were observed in the river in this section. Hook and line sampling yielded a fair number of rainbow and brown trout and flannelmouth and bluehead suckers.

Later in day 5 we looked at the river between Mucho Grande Mine and Ben Canyon. There was some change in riparian vegetation in this section as there was a fair number of boxelders on the first terrace, with willows still dominating woody species found along the riverbanks. The habitat appeared to be stable, had fewer pools with more runs and/or glides present than found upstream. Sampling showed a diverse population of macroinvertebrates, some trout, and a lot of suckers (flannelmouth/bluehead). The largest rainbow trout caught by hook and line sampling was 37.5 cm in total length and weighed .6 kg. The substrate in this reach was composed mostly of gravel and cobble and appeared clean.

Part of the team covered Bradfield Bridge to the Dove Creek Pump Station on day 5. They described the habitat as poor, comparing it to the remainder of the river for trout habitat.

APPENDIX C

Dolores River Hydraulic Geometry Analysis

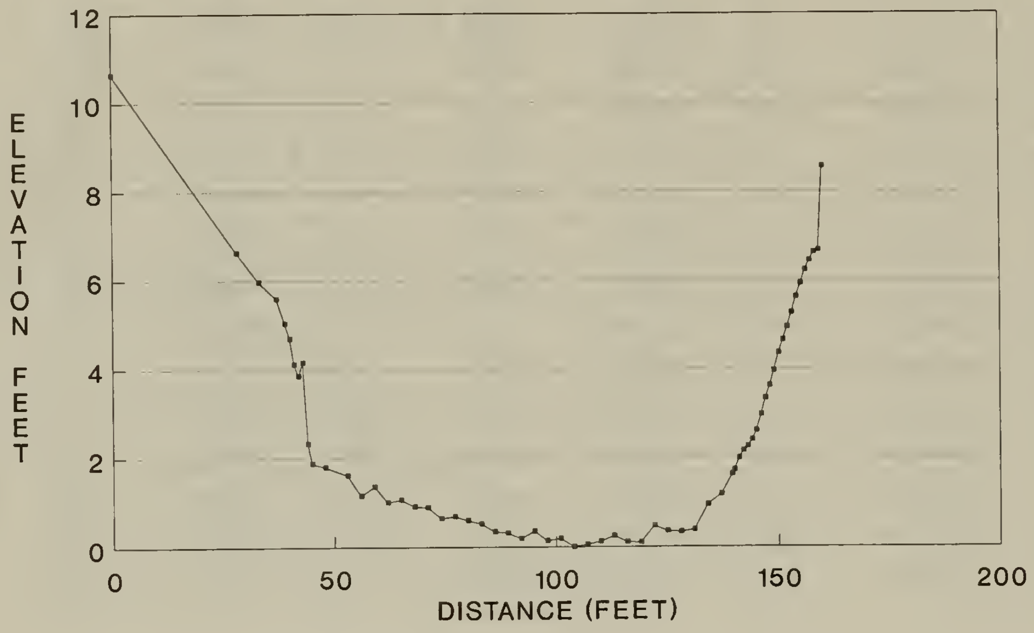
Table B-1. Rating Table, Dolores River Near Bradfield Bridge.

Stage	Disch	Vel	X-Sect Area	Wetted Perim	Hydr Radius	Top Width	Mean Depth
3.000	1030.392	4.533	227.288	103.354	2.199	102.446	2.23
3.179	1167.219	4.752	245.635	104.084	2.360	103.040	2.39
3.357	1310.695	4.963	264.088	104.836	2.519	103.655	2.54
3.536	1459.897	5.165	282.664	105.701	2.674	104.390	2.72
3.714	1616.245	5.363	301.367	106.504	2.830	105.060	2.87
3.893	1776.011	5.547	320.190	107.582	2.976	105.990	3.02
4.071	1931.680	5.693	339.284	109.621	3.095	107.841	3.14
4.250	2102.771	5.863	358.664	110.897	3.234	108.982	3.29
4.429	2284.620	6.041	378.195	111.804	3.383	109.811	3.43
4.607	2471.625	6.212	397.887	112.801	3.527	110.734	3.59
4.786	2663.321	6.375	417.749	113.904	3.668	111.774	3.73
4.964	2860.126	6.533	437.810	115.087	3.804	112.901	3.88
5.143	3062.982	6.687	458.070	116.279	3.939	114.038	4.02
5.321	3271.599	6.837	478.539	117.501	4.073	115.207	4.17
5.500	3486.803	6.985	499.214	118.704	4.206	116.354	4.30

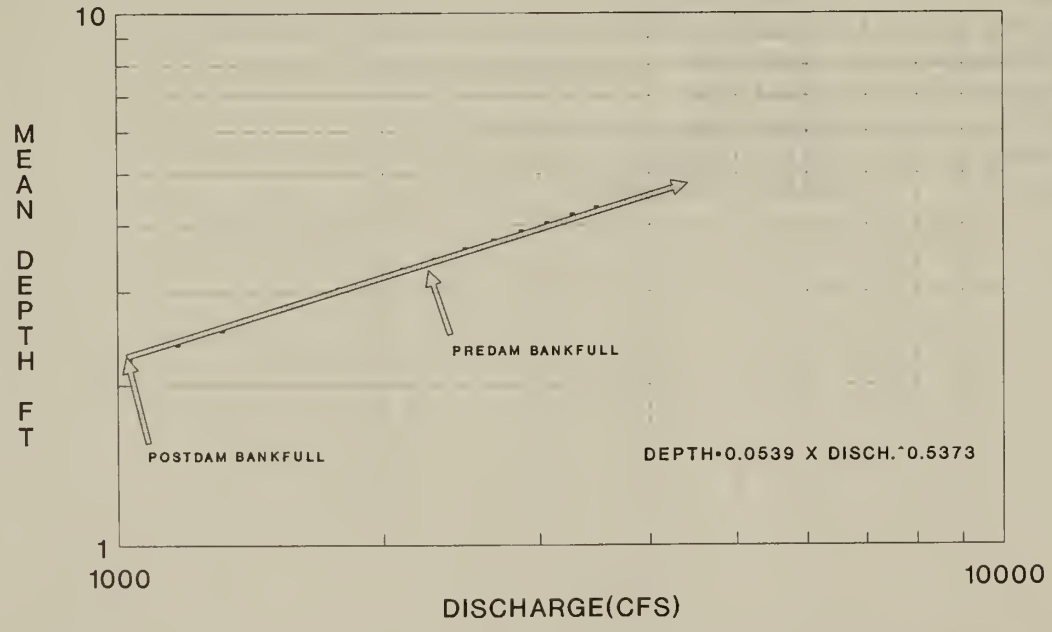
Table B-2. Channel Geometry, Bank-full Stage, Dolores River Near Bradfield Bridge.

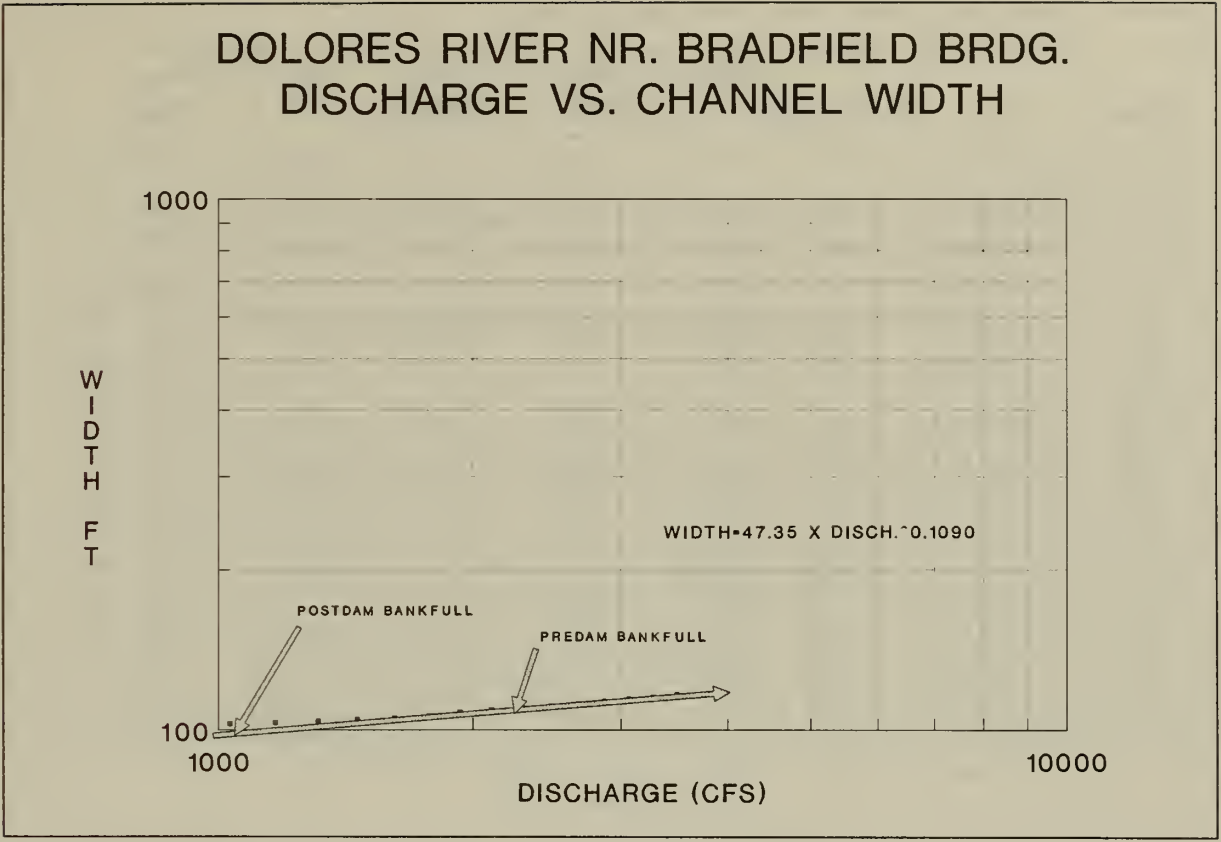
Cross-sectional area = 378.242 sq. feet
Wetted Perimeter = 111.806 feet
Hydraulic Radius = 3.383 feet
Gradient = .0022 feet/foot
Mannings N = .026
Maximum Depth = 4.429 feet
Mean Depth = 3.444 feet
Top Width = 109.813 feet
Mean Velocity = 6.041 feet/sec
Discharge = 2285.061 cubic feet/sec

DOLORES RIVER NR. BRADFIELD BRDG.
CHANNEL CROSS SECTION

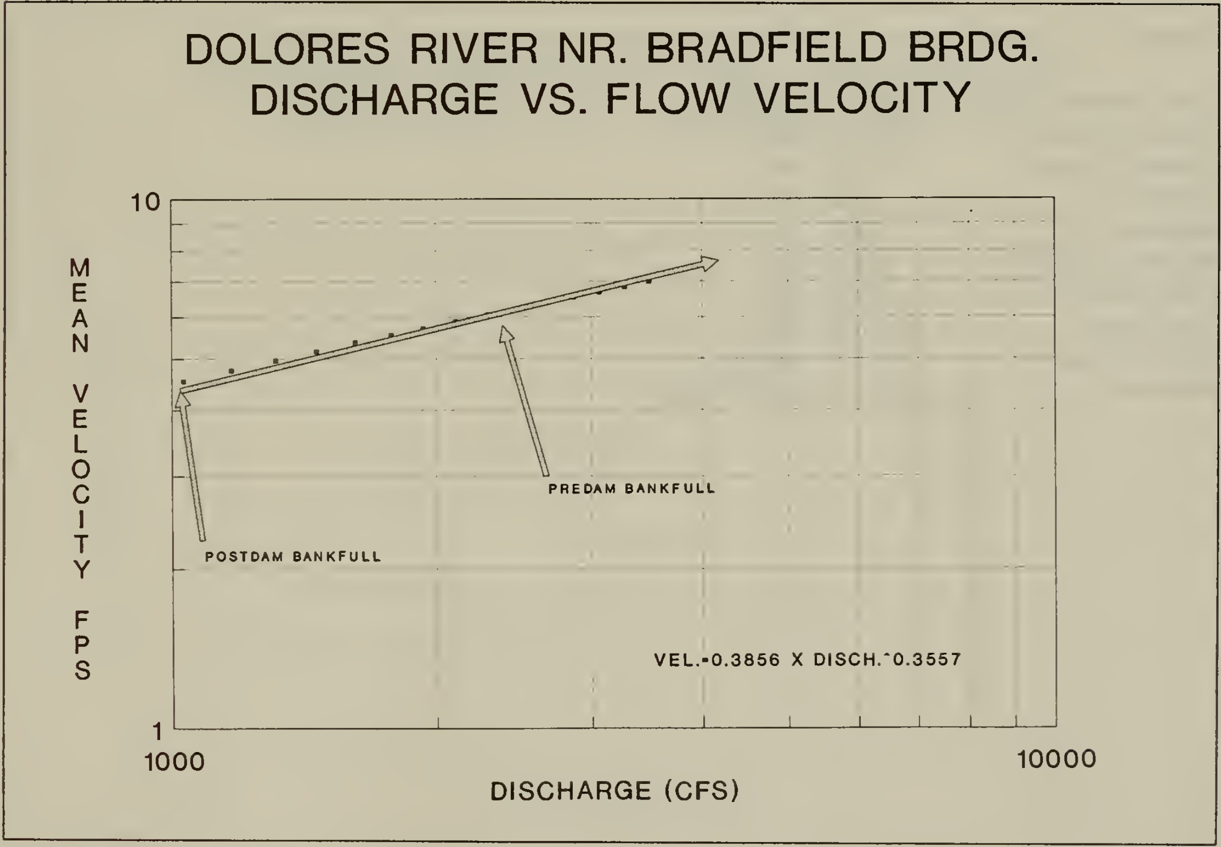


DOLORES RIVER NR. BRADFIELD BRDG.
DISCHARGE VS. CHANNEL DEPTH





DOLORES RIVER NR. BRADFIELD BRDG.
DISCHARGE VS. CHANNEL WIDTH



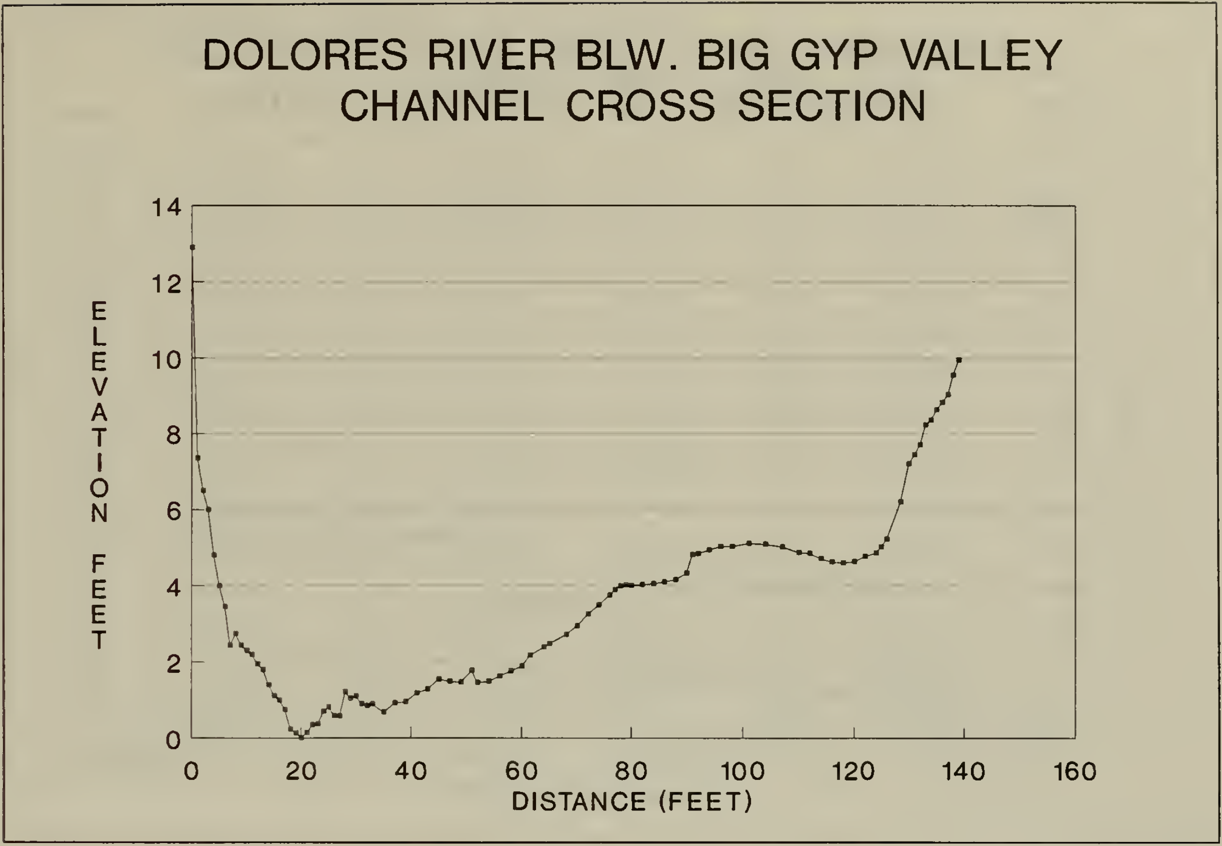
DOLORES RIVER NR. BRADFIELD BRDG.
DISCHARGE VS. FLOW VELOCITY

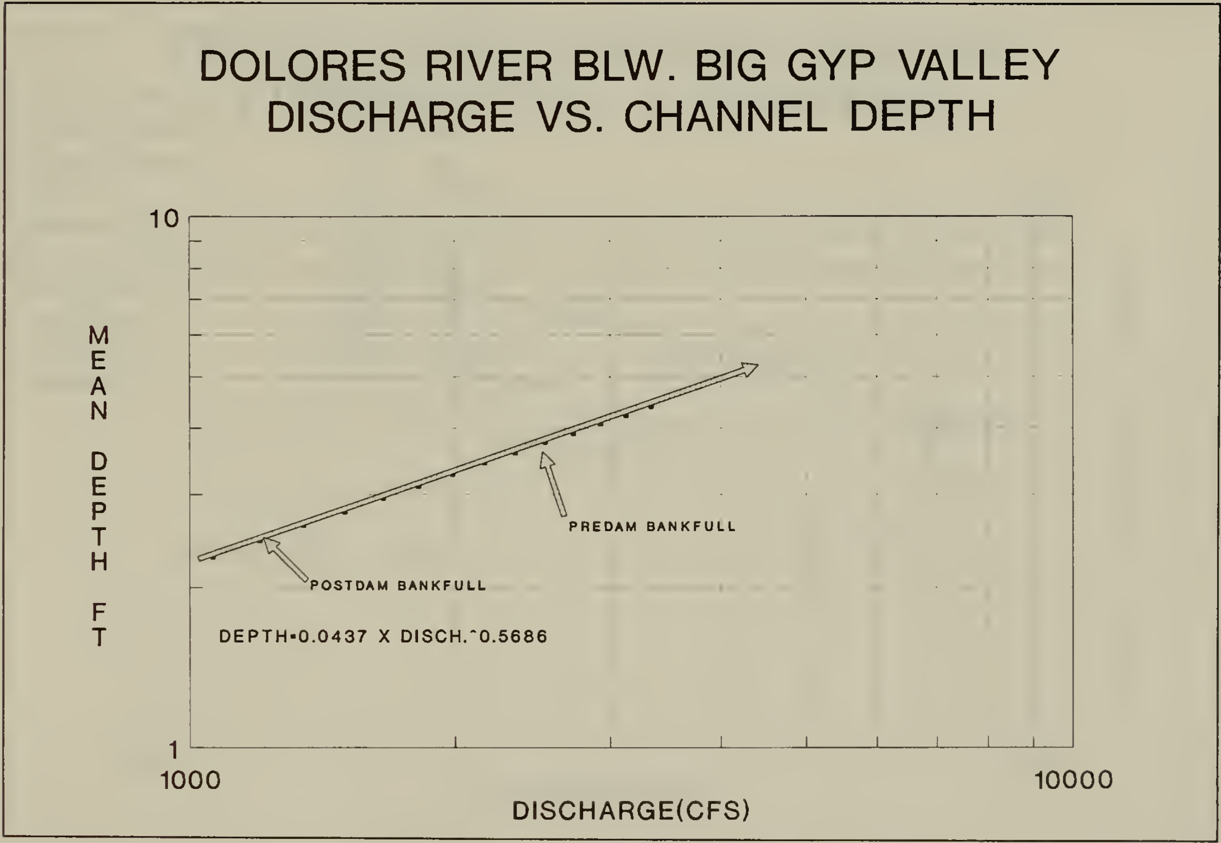
Table B-3. Rating Table, Dolores River Below Big Gyp Valley.

Stage	Disch	Vel	X-Sect Area	Wetted Perim	Hydr Radius	Top Width	Mean Depth
5.179	1062.396	3.801	279.518	124.370	2.247	122.094	2.29
5.357	1199.713	3.981	301.384	125.113	2.409	122.718	2.46
5.536	1344.364	4.158	323.343	125.749	2.571	123.229	2.63
5.714	1495.576	4.330	345.394	126.385	2.733	123.739	2.79
5.893	1653.221	4.498	367.536	127.020	2.894	124.250	2.96
6.071	1816.519	4.660	389.773	127.729	3.052	124.852	3.12
6.250	1985.253	4.817	412.131	128.524	3.207	125.563	3.28
6.429	2160.134	4.970	434.616	129.320	3.361	126.273	3.44
6.607	2341.896	5.122	457.224	130.045	3.516	126.900	3.60
6.786	2530.181	5.272	479.936	130.723	3.671	127.471	3.76
6.964	2724.379	5.419	502.749	131.401	3.826	128.042	3.93
7.143	2924.417	5.563	525.665	132.079	3.980	128.612	4.09
7.321	3126.516	5.698	548.698	133.004	4.125	129.444	4.24
7.500	3334.079	5.830	571.886	133.947	4.270	130.229	4.39

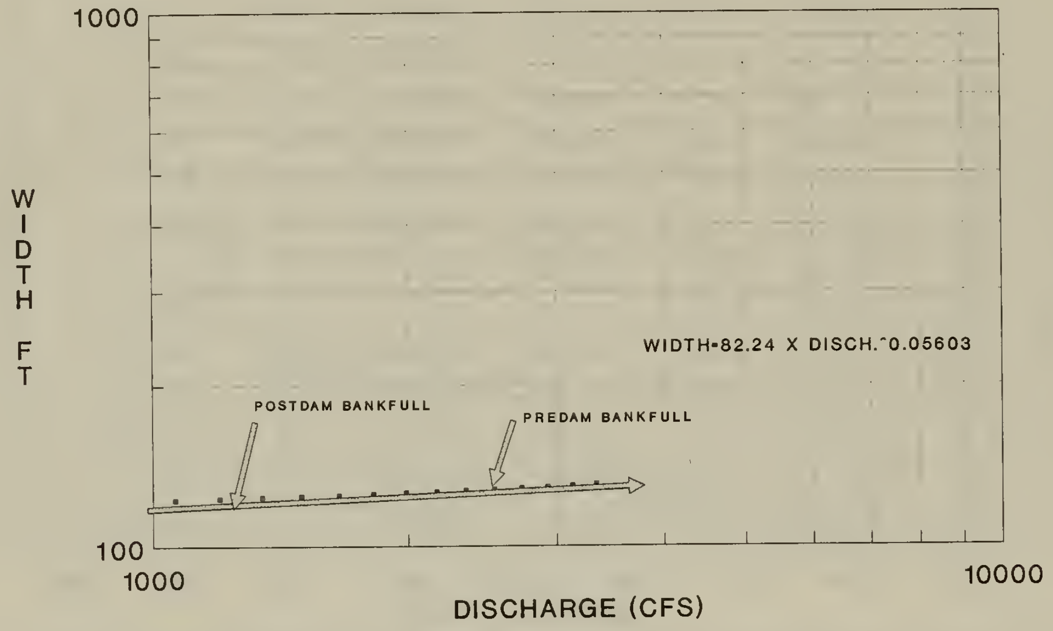
Table B-4. Channel Geometry, Bank-full Stage, Dolores River Below Big Gyp Valley.

Cross-sectional area = 488.137 sq. feet
Wetted Perimeter = 130.967 feet
Hydraulic Radius = 3.727 feet
Gradient = .0020 feet/foot
Mannings N = .030
Maximum Depth = 6.850 feet
Mean Depth = 3.823 feet
Top Width = 127.676 feet
Mean Velocity = 5.325 feet/sec
Discharge = 2599.417 cubic feet/sec


DOLORES RIVER BLW. BIG GYP VALLEY
CHANNEL CROSS SECTION
ELEVATION FEET
0
2
4
6
8
10
12
14
0
20
40
60
80
100
120
140
160
DISTANCE (FEET)


DOLORES RIVER BLW. BIG GYP VALLEY
DISCHARGE VS. CHANNEL DEPTH
MEAN DEPTH FT
10
1
1000
10000
DISCHARGE(CFS)
PREDAM BANKFULL
POSTDAM BANKFULL
DEPTH=0.0437 X DISCH.^0.5686

DOLORES RIVER BLW. BIG GYP VALLEY
DISCHARGE VS. CHANNEL WIDTH



DOLORES RIVER BLW. BIG GYP VALLEY
DISCHARGE VS. FLOW VELOCITY

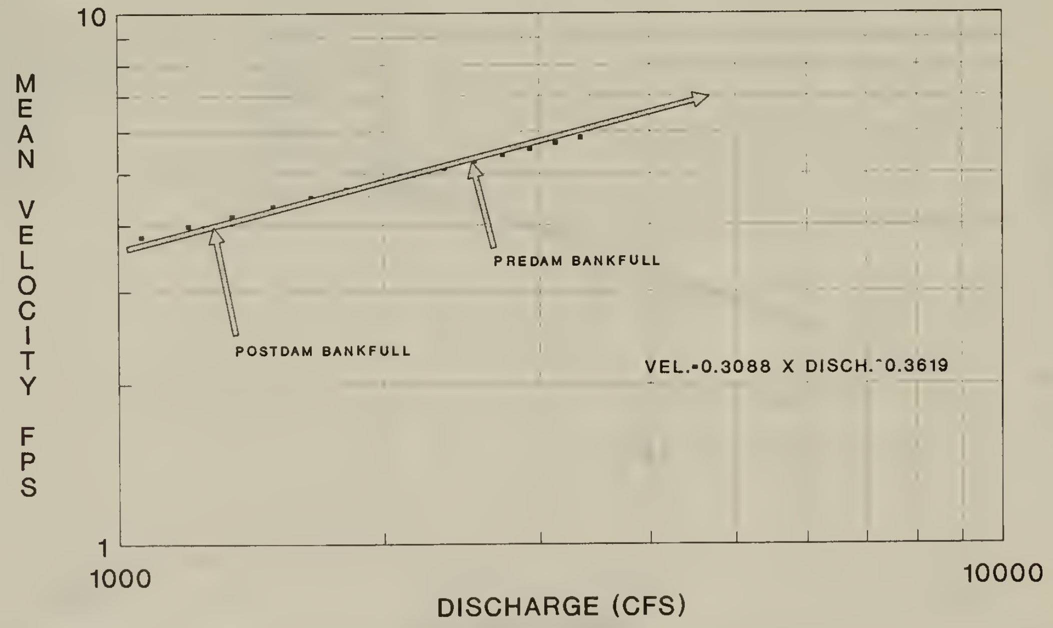
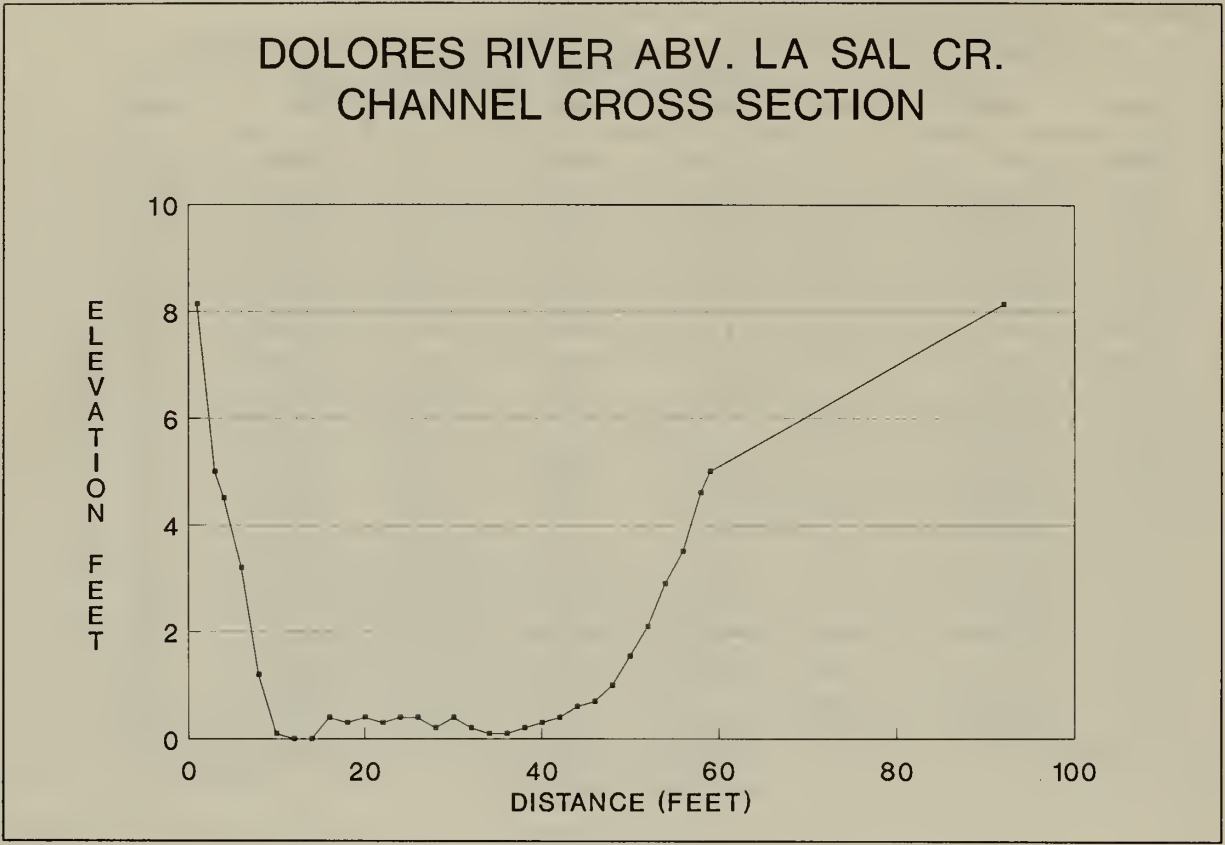


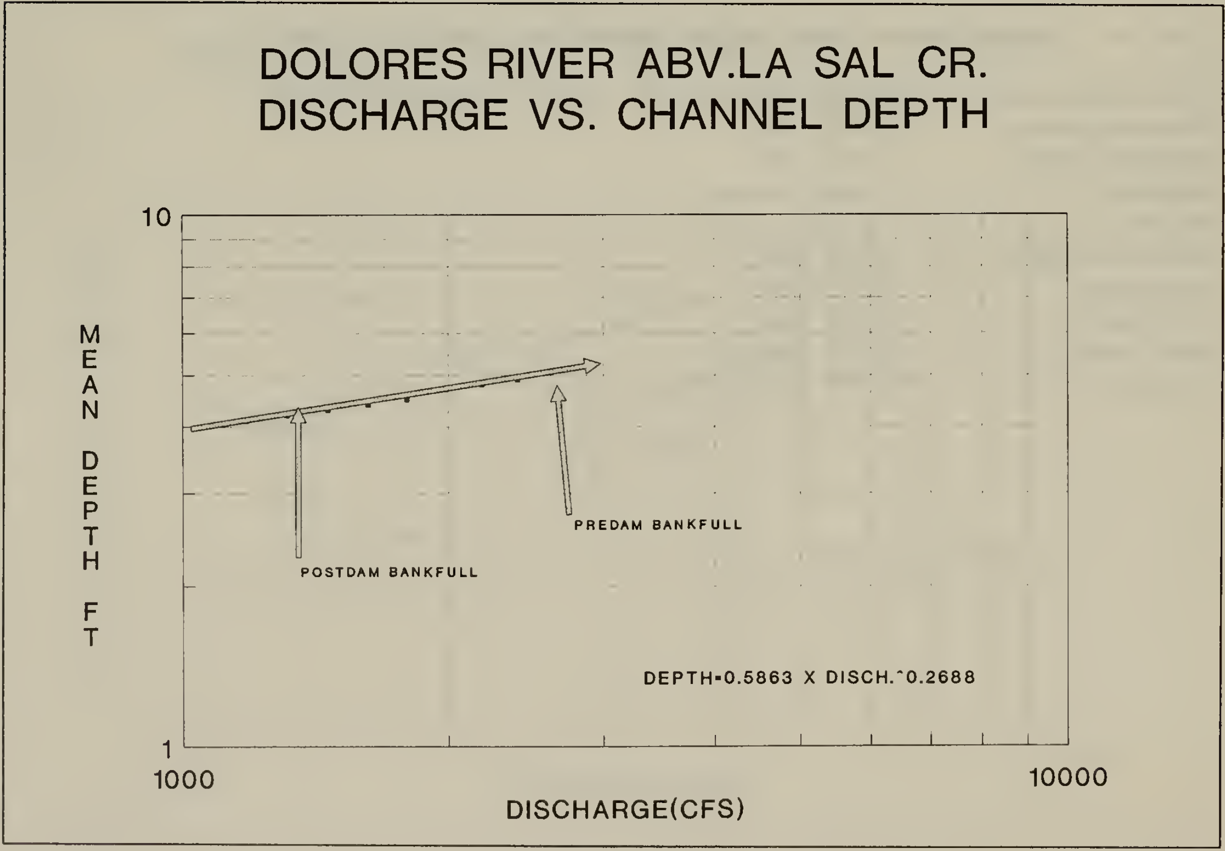
Table B-5. Rating Table, Dolores River Above La Sal Creek.

Stage	Disch	Vel	X-Sect Area	Wetted Perim	Hydr Radius	Top Width	Mean Depth
5.000	1134.172	5.173	219.250	58.491	3.748	56.000	3.92
5.224	1210.688	5.217	232.049	61.117	3.797	58.492	3.97
5.447	1292.292	5.266	245.404	63.742	3.850	60.984	4.02
5.671	1379.082	5.318	259.317	66.367	3.907	63.476	4.09
5.894	1471.163	5.373	273.787	68.993	3.968	65.968	4.15
6.118	1568.643	5.431	288.814	71.618	4.033	68.460	4.22
6.341	1671.632	5.492	304.399	74.243	4.100	70.952	4.29
6.565	1780.242	5.554	320.540	76.869	4.170	73.444	4.37
6.789	1894.584	5.618	337.239	79.494	4.242	75.936	4.44
7.012	2014.775	5.684	354.495	82.119	4.317	78.428	4.52
7.236	2140.930	5.750	372.307	84.745	4.393	80.920	4.60
7.459	2273.161	5.819	390.678	87.370	4.472	83.412	4.68
7.683	2411.586	5.888	409.605	89.995	4.551	85.904	4.77
7.906	2556.319	5.958	429.089	92.621	4.633	88.396	4.85
8.130	2707.475	6.028	449.131	95.246	4.715	90.889	4.94

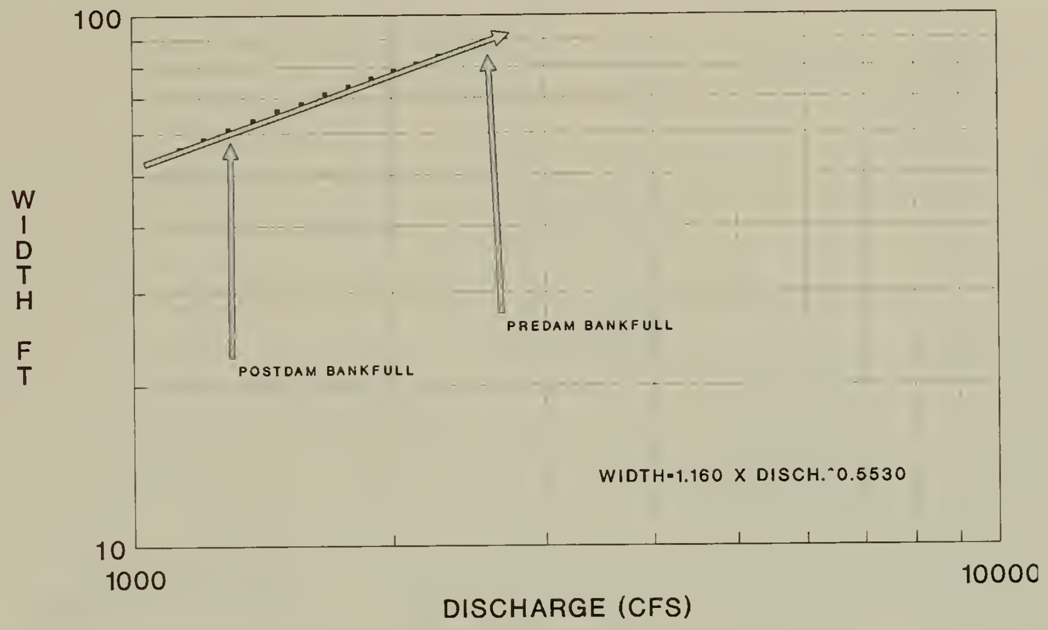
Table B-6. Channel Geometry, Bank-full Stage, Dolores River Above La Sal Creek.

Cross-sectional area = 449.131 sq feet
Wetted Perimeter = 95.246 feet
Hydraulic Radius = 4.715 feet
Gradient = .0020 feet/foot
Mannings N = .031
Maximum Depth = 8.130 feet
Mean Depth = 4.942 feet
Top Width = 90.889 feet
Mean Velocity = 6.028 feet/sec
Discharge = 2707.476 cubic feet/sec

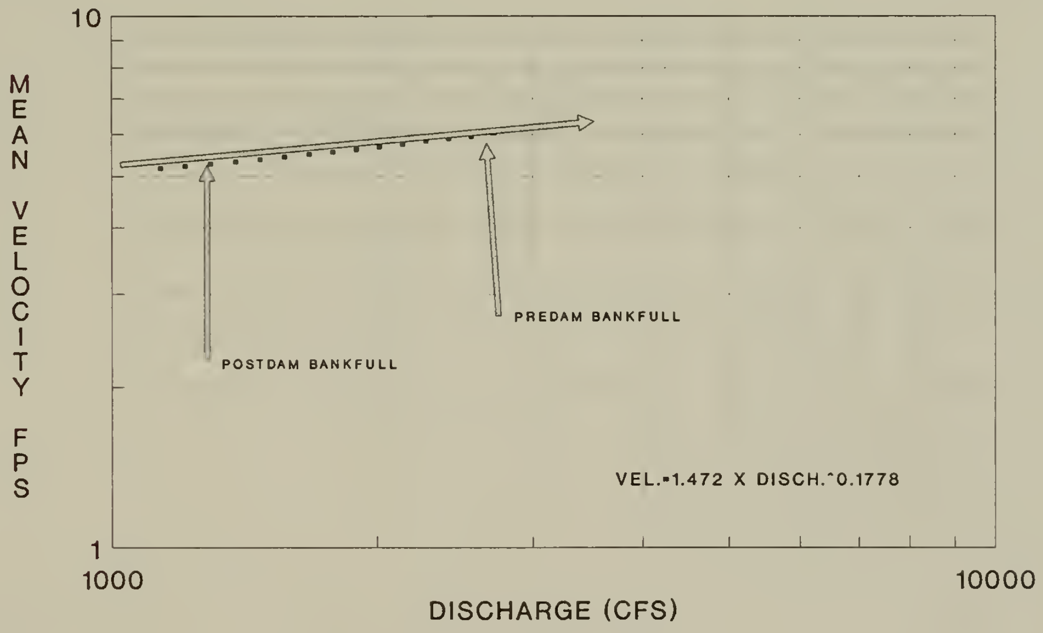

DOLORES RIVER ABV. LA SAL CR.
CHANNEL CROSS SECTION

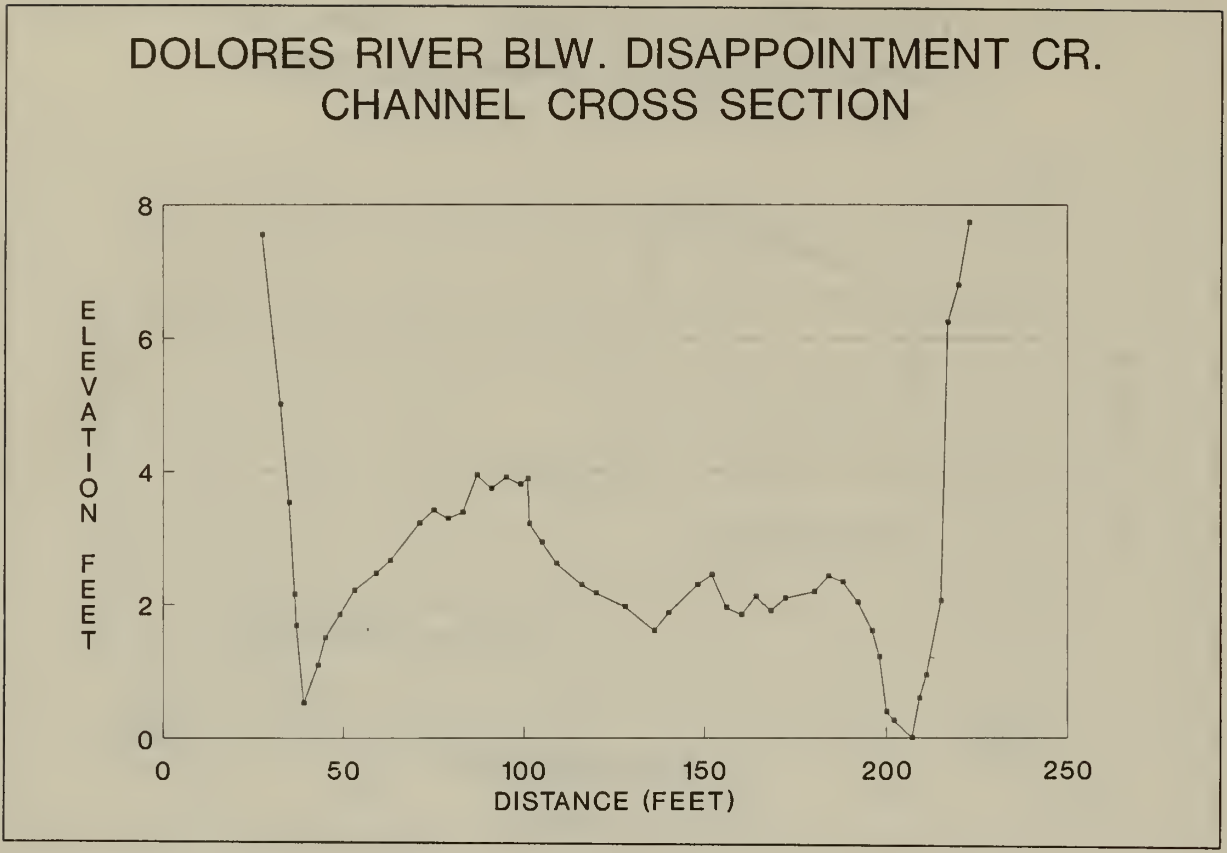

DOLORES RIVER ABV.LA SAL CR.
DISCHARGE VS. CHANNEL DEPTH

DOLORES RIVER ABV. LA SAL CR.
DISCHARGE VS. CHANNEL WIDTH



DOLORES RIVER ABV. LA SAL CR.
DISCHARGE VS. FLOW VELOCITY





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CHANNEL CROSS SECTION

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